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of

Western Pennsylvania

VOLUME 26

FEBRUARY 1910—JANUARY 1911

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PROCEEDINGS OF THE

Engineers' Society of Western Pennsylvania

VOLUME 26

THE SUBSTRUCTURE OF THE P. & L. E. R. R. BRIDGE OVER THE OHIO RIVER AT BEAVER, PA.

BY A. R. RAYMER*

This bridge is located about twenty-five miles below Pittsburgh where the main line of the P. & L. E. R. R. crosses the Ohio River from Monaca on the south shore to Beaver on the north shore.

The new bridge is located about three hundred feet up stream from the old one, and about one half mile below the junction of the Beaver River with the Ohio, and nearly the same distance below the point in the Ohio where it changes its course from a northerly to a westerly direction.

SOME REASONS FOR BUILDING THE NEW BRIDGE

The present single, gauntleted track bridge is at the summit of a compensated maximum grade (0.3 per cent.) southbound with double track approaches and four track construction approaching completion on each side of the river. The masonry supporting the old bridge is not adequate for use with a double track structure, and the length of the channel span has never been quite satisfactory to the river interests, and in addition to these reasons the operating conditions have made it very desir-

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*Assistant Chief Engineer, The Pittsburgh and Lake Erie Railroad Company, Pittsburgh.

able to flatten the sharp curves in the approaches hence the reasons for building the new bridge and also for changing its location.

The new bridge now being erected, shown in Fig 1, is the third one constructed since the road was built in 1878.

RIVER CONDITIONS

The river at this point is in the pool above dam No. 6 at Merrill, Pa. The elevation of "low water" is 661.2 and of pool full 668.3, and the flood level, or high water, is 707.5, all referred to Sandy Hook datum.

The location of the channel at low water, and also at pool full, is just outside of the crib on the Monaca shore, while the channel at coal boat stages of ten to fifteen feet above low water, as determined by floats liberated under the center of the channel span of the suspension bridge at Rochester, and located at frequent intervals by transit line intersections, is close to new pier No. 3, and outside of the river end of the present channel span. The river conditions near this bridge, due to bars, variations in currents caused by the junction with the Beaver, and chiefly on account of the ninety degree sweep in the direction of the channel, are such that false work could not be allowed in the channel span in justice to the river shipping interests. These conditions made the cantilever form of construction desirable. Ice conditions at this point are not serious, ice may run in dense masses for days, but the cakes are not large enough to cause trouble.

CHANNEL SPAN LENGTH AND CLEARANCE

The length of the channel span was determined by making it conform with the practice of the U. S. Engineers in the construction of the bear trap dams above and below the bridge location.

These dams are made with a clear channel width of 700 ft. After allowing for the skew angle of crossing, and for the width of masonry piers, the length of the channel span necessary to

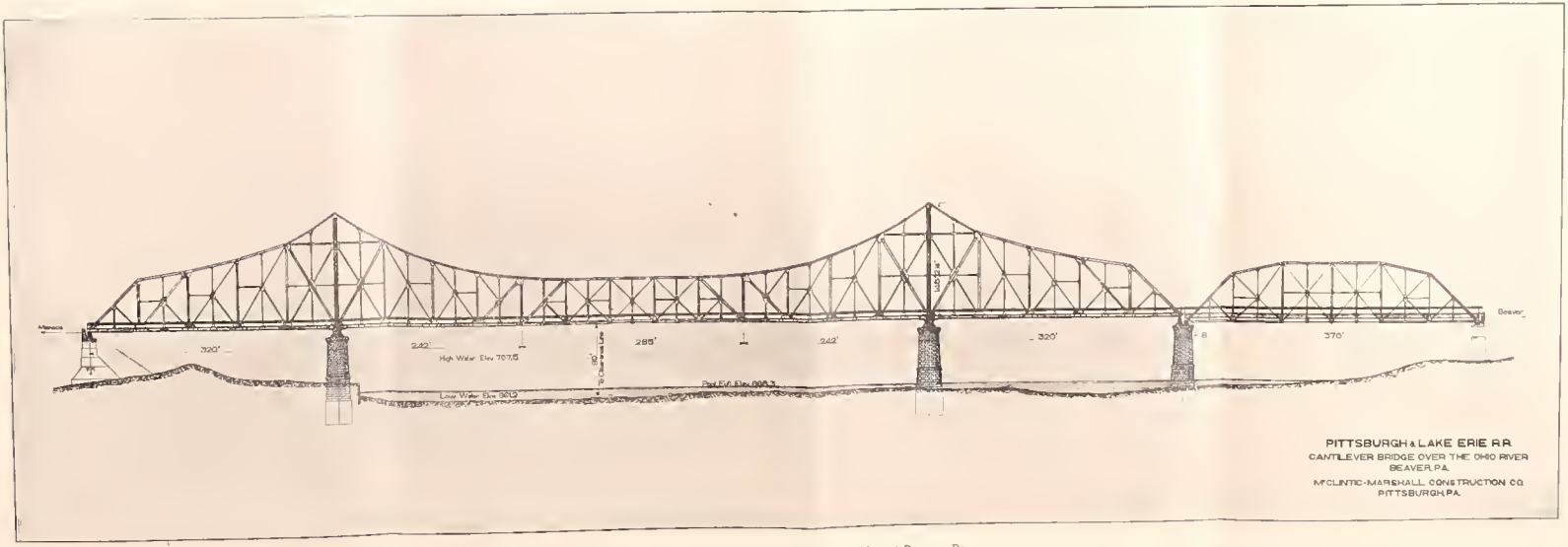

Fig. 1. Pittsburgh and Lake Erie R. R. Bridge at Beaver, Pa.

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give a river channel of the above width is 769 ft., center to center of bearings. The total length of the bridge from backwall to backwall of abutments is 1800 ft., made up of two anchor arms of 320 ft. each, one channel span of 769 ft., one approach span of 370 ft. and 8 ft. between the approach span and the anchor arm and 6.5 ft. from end pins to backwalls. The distance from low water level to the clearance line under the bridge is 90 ft. as required by the Ohio River Bridge Law.

SCHEDULE OF CONSTRUCTION

As the records show that the usual high water conditions occur in March and April each year, with a comparative freedom from dangerous floods at other periods, it was decided that the schedule of procedure should be arranged to provide that the masonry should be commenced as soon as the water conditions after the flood in the spring of 1908 would allow, and pushed to completion before the end of the year. This was done and the work was completed, with the exception of parts of piers 3 and 4 above pool full, which were completed after the high water in the spring of 1909.

TAPES TESTED BY BUREAU OF STANDARDS

Before commencing the survey to define the masonry locations a steel tape 100 ft. long was sent to the Bureau of Standards at Washington, D. C., to be tested, under given temperature and tension conditions, and compared with the standards. This tape when returned with its record became the standard for all measurements made on the work. The tapes were used under uniform tension conditions, and corrections were made for temperature; 60 deg. fahr. being the basis for all work.

SOUNDINGS MADE BY DRILLING

After the piers and abutments were located, diamond drills were used to determine the nature of the material available for foundations. It was decided that two test holes should be made at each foundation location, and from the information thus se-

cured it would be determined whether other holes would be needed. The data derived in this manner showed such uniformity in the quality of the rock and in the slope of its surface, that other holes were deemed unnecessary. Each test hole was continued after striking rock, far enough into it, to remove any doubt about it being bed rock. The material found was water bearing gravel from the bed of the river to the rock surface. The rock used for the foundations is gray and black shale at some points and sand stone at others. The cores removed by the diamond drills are about 2.75 in. in diameter and from 3 to 6 in. long. The rock when exposed in the caissons showed an eroded surface with some pot holes and other local irregularities, evidently caused by water at some remote period.

GENERAL OUTLINE

The substructure consists of two abutments and three piers. The abutments are composed almost entirely of concrete, only the portions exposed after completion being faced with Beaver Valley sandstone. The piers are wholly of concrete from the rock up to low water line, and of concrete faced with Beaver Valley sandstone from that line to the top.

The concrete is made of one quality of the proportions of one part of portland cement, to three parts of clean sharp river sand to five parts clean gravel thoroughly mixed and used soft enough to puddle.

On all of this work the Railroad Company furnished the cement on cars at the site, after which the contractor was responsible for it, reporting daily the amount used. The contractor was charged for the cement bags and an allowance was made for all that were returned in good condition.

There are many reasons for recommending the practice of the Railroad Company furnishing the cement needed on work done by contract. On account of the anchorages and the bearings on grillages running through the bridge seats and the pier copings and also because of the large size of the exposed top surfaces of the masonry, unusual problems presented themselves as to how these surfaces should be finished and protected

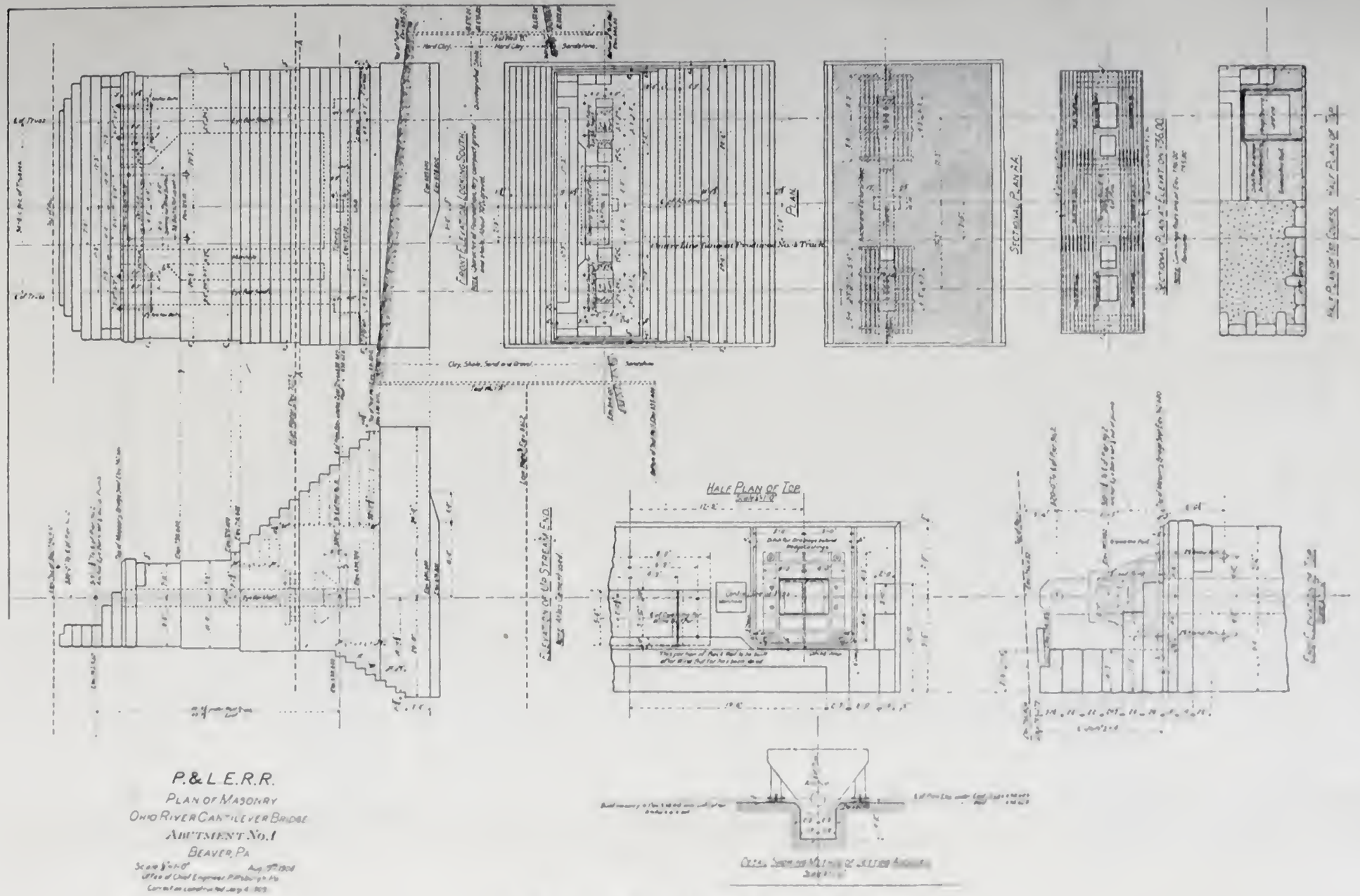

Fig. 2. Plan of Abutment No. 1

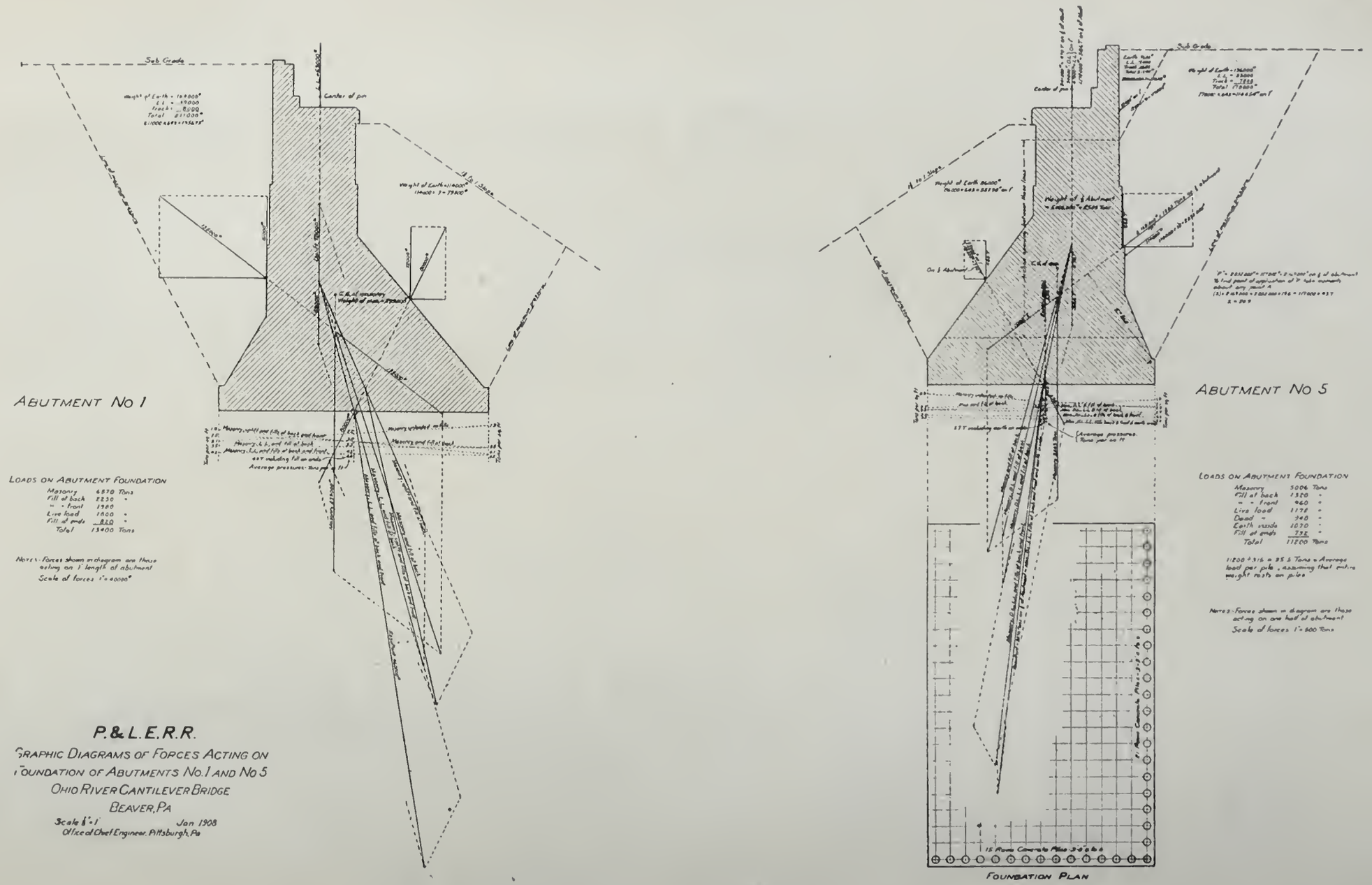
Sub Grade
Center of pin
ABUTMENT No 1
LOADS ON ABUTMENT FOUNDATION
Masonry 6870 Tons
Fill at back 5230 "
" " front 1980 "
Live load 1800 "
Fill at ends 820 "
Total 13400 Tons
Scale of forces 1" = 40000#
P. & L. E. R. R.
GRAPHIC DIAGRAMS OF FORCES ACTING ON FOUNDATION OF ABUTMENTS No. 1 AND No 5
OHIO RIVER CANTILEVER BRIDGE
BEAVER, PA
Scale 1" = 1'
Jan 1908
Office of Chief Engineer, Pittsburgh, Pa
ABUTMENT No 5
LOADS ON ABUTMENT FOUNDATION
Masonry 5006 Tons
Fill at back 1320 "
" " front 960 "
Live load 1176 "
Dead " 340 "
Earth inside 1070 "
Fill at ends 735 "
Total 11200 Tons
Scale of forces 1" = 800 Tons
FOUNDATION PLAN

Fig. 3. Stress Sheet of Abutments Nos. 1 and 5

from the weather. This was solved by using a granolithic pavement, sloped for drainage, on all bridge seats and pier copings.

ABUTMENT NO. 1

Abutment No. 1, shown in Fig. 2, is the anchorage at the south end of the bridge and is located where the top of rail elevation is 66 ft. above the ground surface and about one hundred and ten feet above the rock.

It was necessary to have this structure not only heavy enough to act alternately as a support and as an anchor, but also properly designed to distribute the load practically uniformly over the base to prevent any horizontal motion in case of settlement. Corrections could be made in the length of the bars for any vertical motion, but nothing could be done to correct for any horizontal motion, after the anchors were embedded in the concrete.

The soundings showed good material between the surface of the ground and the rock, 44 ft. below.

It was at first thought necessary to extend the masonry to the rock or to use concrete piles, wooden piles being out of the question, above water level, and on account of the enormous loads.

The thickness of the masonry at the ground line necessary to make it reasonably stable as a retaining wall while the 66 ft. embankment would be under construction and until it had fully settled, made the extension of the masonry to the rock a no small item of expense.

Concrete piles were then considered, the abutment was designed to make a uniform distribution of the loading on the foundation. The loading is as follows:

Masonry	6570 tons
Vertical component of fill at back	2230 "
" " " " " front	1980 "
" " " " " ends	820 "
Live load	1800 "
	13400 "

The minimum size of the masonry at the bottom needed to accomplish this was 54 ft. lengthwise with the track, by 57 ft. wide. This made a pressure of 4.4 tons per sq. ft., and assuming the piles to be located on 3 ft. centers a loading of over 39 tons per pile.

It will easily be seen that the method, frequently followed, of designing walls or abutments to keep the resultant within the *middle third* would not answer in this case, it had to be located at the middle point. The plans were made for the use of concrete piles, 16 in. diameter and spaced 3 ft. center to center. After the foundation excavation had been made the material was found to be better than was supposed from the sounding information, and quite good enough to support four to five tons per square foot. The piles were then dispensed with and the masonry of the same size and design was founded on the clay and shale. The results have shown the wisdom of the course pursued.

The intensity of the foundation stresses in tons per square foot under the varying loads applied separately and in combinations is as shown in Fig. 3 and the following table:

	Intensity of Stress	
	At back.	At front.
Masonry unloaded, no fills	3.1	1.3
Masonry unloaded, with fill at back.....	2.5	3.5
Masonry, Live load and fill at back	3.5	3.5
Masonry, Live load and fill at back and front	4.2	4.2
Masonry, Live load fills back, front and at ends	4.4	4.4
Masonry, Live load uplift and all fills.....	1.9	4.1

Vertical shaft openings from the bridge seat down 48 ft. to the bottom of the anchor grillage were built in the masonry, one for each cluster of eyebars and one for a man hole; these openings are connected by a horizontal passage at the bottom, to allow the 14 in. pins to be driven, a drain connects the low point with the exterior of the masonry. The shafts and the passage or tunnel at the bottom are designed so as to facilitate the work of filling them with concrete. During the period when the fill was being made around this abutment it settled 0.5 in.

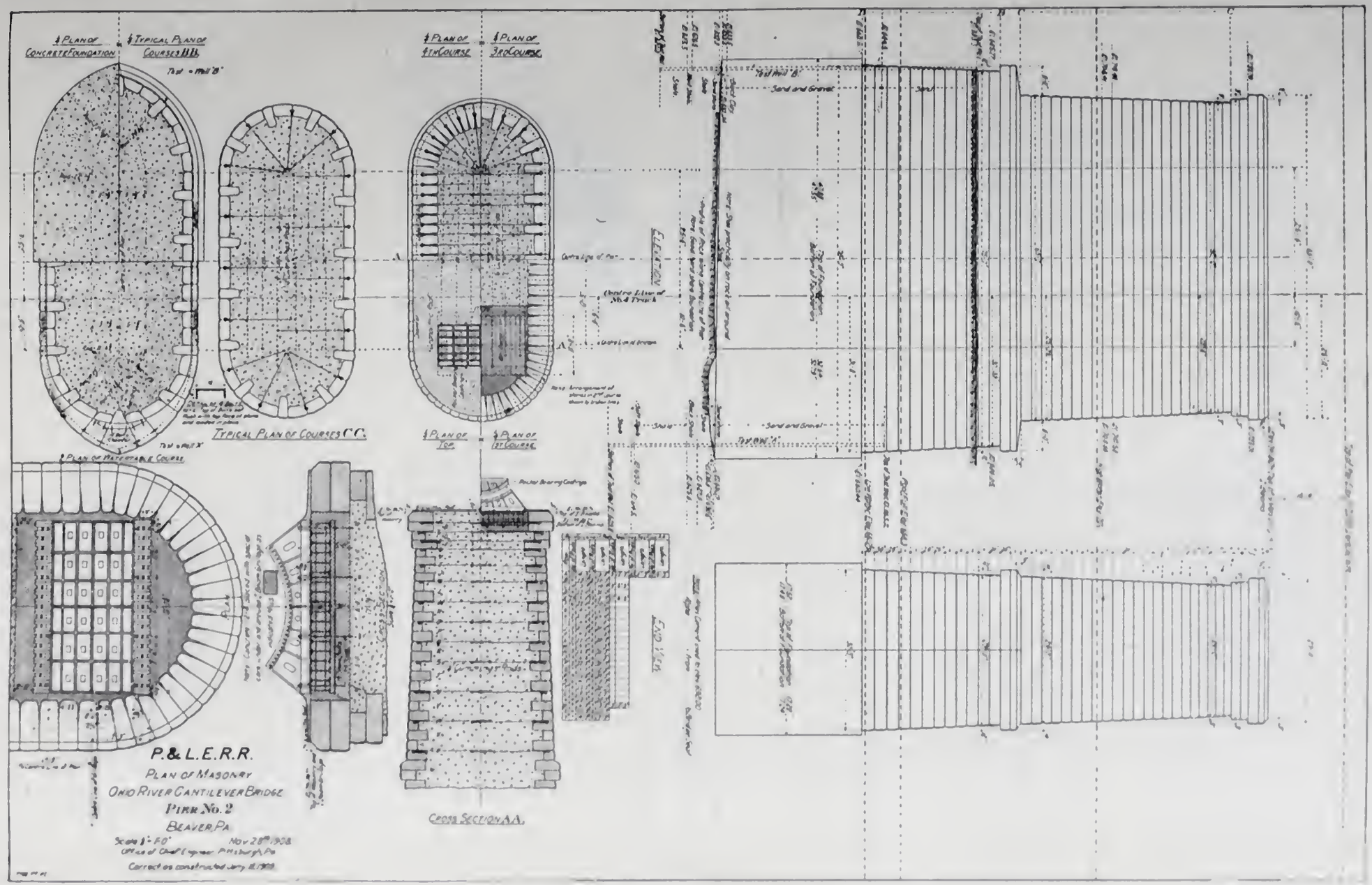

Fig. 4. Plan of Pier No. 2

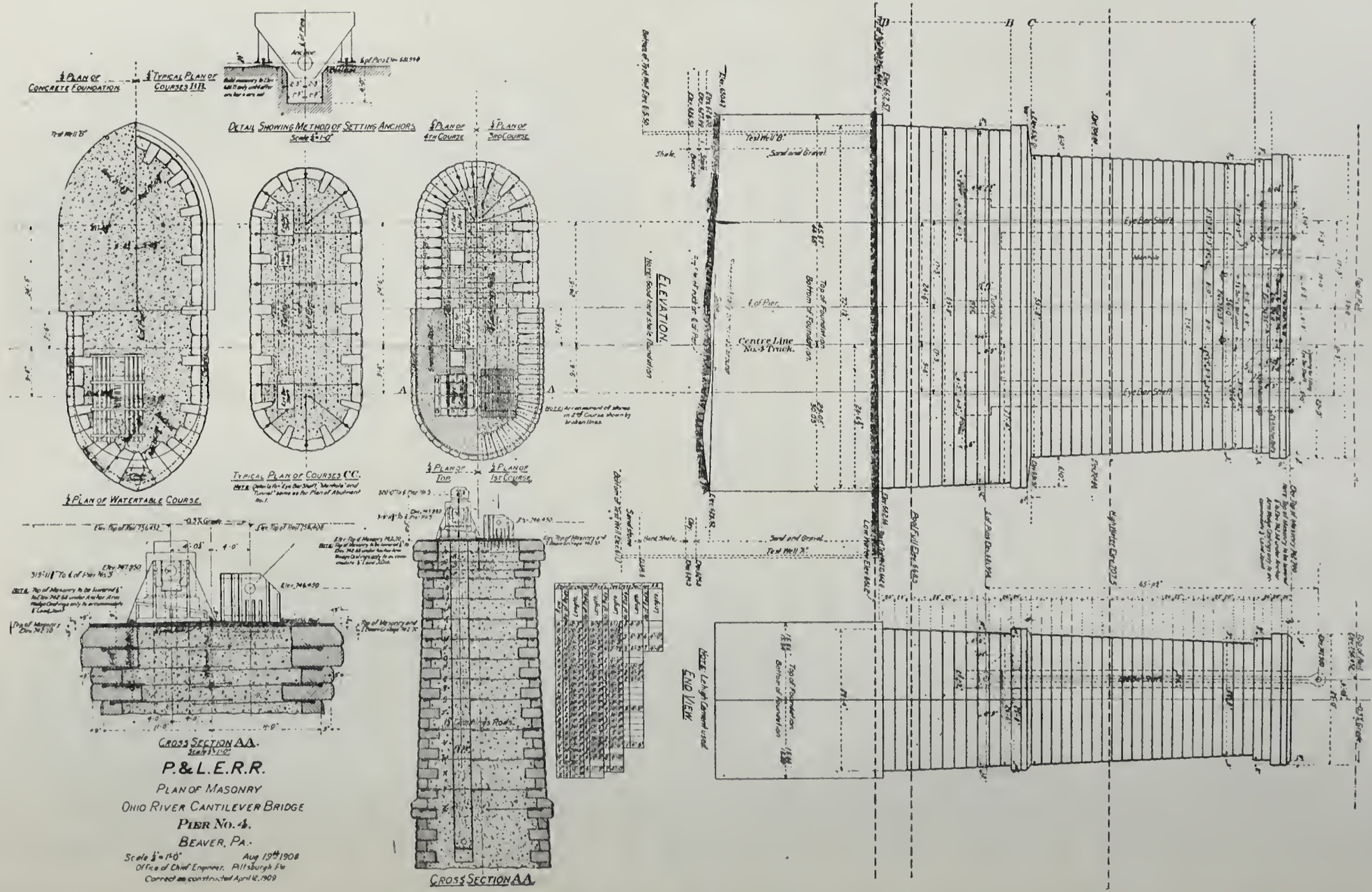
½ Plan of Concrete Foundation
½ Typical Plan of Courses I to B.
Detail Showing Method of Setting Anchors
Scale ½"=1'-0"
½ Plan of 4th Course
½ Plan of 3rd Course
½ Plan of Watertable Course.
Typical Plan of Courses C.C.
½ Plan of Top
½ Plan of 1st Course
Elevation.
End View
Cross Section AA.
Scale ½"=1'-0"
P. & L. E. R. R.
Plan of Masonry
Ohio River Cantilever Bridge
Pier No. 4.
Beaver, Pa.
Scale ½"=1'-0" Aug 19th 1908
Office of Chief Engineer. Pittsburgh Pa
Correct as constructed April 12, 1909
Cross Section AA.

Fig. 5. Plan of Pier No. 4

vertically with no motion horizontally; the fill was made by slope from the top and not in horizontal layers. This settlement was undoubtedly due to the compression of the material under the loading of the embankment at and around the abutment. This abutment contains about 3922 cu. yd. of masonry.

PIERS NOS. 2, 3 AND 4

Piers Nos. 2 and 3 are the main channel piers, and are practically the same in design and are shown in Fig. 4. Pier No. 4 is the anchor at the Beaver end of the cantilever and is shown in Fig. 5. The bridge loads on the channel piers amount to 6000 tons under each truss on each pier, or a total of 12 000 tons per pier. These three pieces of masonry are founded on rock about one hundred and twenty-six feet below top of rail elevation. At the rock surface the stresses are 8 tons per sq ft. due to masonry loads and 5 tons for the bridge load, a total of 13 tons per sq. ft.

The bridge load is delivered to the masonry on the channel piers through cast steel shoes, having each a masonry contact of 150 sq. ft., or 80 tons per sq. ft. These shoes rest on I-beam grillages with a bottom distributing surface of 240 sq. ft. loaded to an intensity of 25 tons per sq. ft., about 350 lbs. per sq. in. Rods, 1.25 in. diameter, placed in alternate layers crosswise and endwise of the piers were used in the first fifty feet below the grillages to help in the distribution of the concentrated loads. No allowance was made in the design for the compression of these piers under full live load. This compression under the bridge loading amounts to 0.75 in. on pier No. 2 and 0.625 in. on pier No. 3.

When the invitations for bids were sent to the contractors it was specified that these piers would be founded on rock, and that the concrete would be laid in *the dry;* the method to be followed in doing so was not specified. The propositions received were all, excepting one, based on the usual pneumatic methods; the other bidder, the low one, figured on using concrete caissons, the outside outlines of which were to conform with the foundation lines, with the vertical dimension equal to the distance from low water line to the rock surface. These caissons

to have vertical excavating chambers, through the concrete, and cutting edges around the under side of the exterior walls, so arranged that they would settle or move downward as the material was excavated from the interior. As the low bidder had previously constructed several smaller foundations of this kind, this method was approved.

The specifications used with the contract read as follows:

"Pneumatic caissons will be used in constructing foundations for Piers Nos. 2, 3 and 4. Compressed air will be used, at least for the excavation close to the rock, for leveling and preparing the rock, for fitting the caissons to the rock, and for placing enough concrete in them to properly seal, in the opinion of the Chief Engineer the bottom of the caissons against the water pressure and to hold it in place until the concrete shall have set."

Otherwise the contractor was allowed considerable liberty in the method of sinking the foundations, the methods being subject at all times to the approval of the Chief Engineer.

Pier No. 4 being an anchor similar to that at abutment No. 1, the details of the anchor construction and of the vertical openings, etc., are identical. This method of placing the anchor I-bars after the completion of the masonry is to be commended.

The open caisson method, shown in Fig. 6, which was used worked well under the conditions met; it must, however, be admitted that the weather conditions from May to December while the work was under progress were unusually favorable for this method. During this period the river did not rise more than two feet, and the caissons and coffer dams were not flooded at any time. Had it been otherwise the results would have been equally certain, but the delays due to the floods would have been more or less serious. The open caissons were built with their bases practically at the low water line, with three vertical working chambers extending from the bottom to the top, the outer wall being about seven feet thick and chisel edged at the bottom, the outside surface being vertical, the inside being beveled by steps to the inside vertical walls. Steps were used instead of plane surfaces to provide a better connection between the final concrete filling in these working chambers and the caisson walls.

After the open caissons were formed and the concrete was properly set the work of sinking them to the rock and founding them on it was commenced by excavating the material through the working chambers by the use of orange peel dredges, as the material was removed, which had to be done with judgment. The weight of the caisson resting on its cutting edge caused it

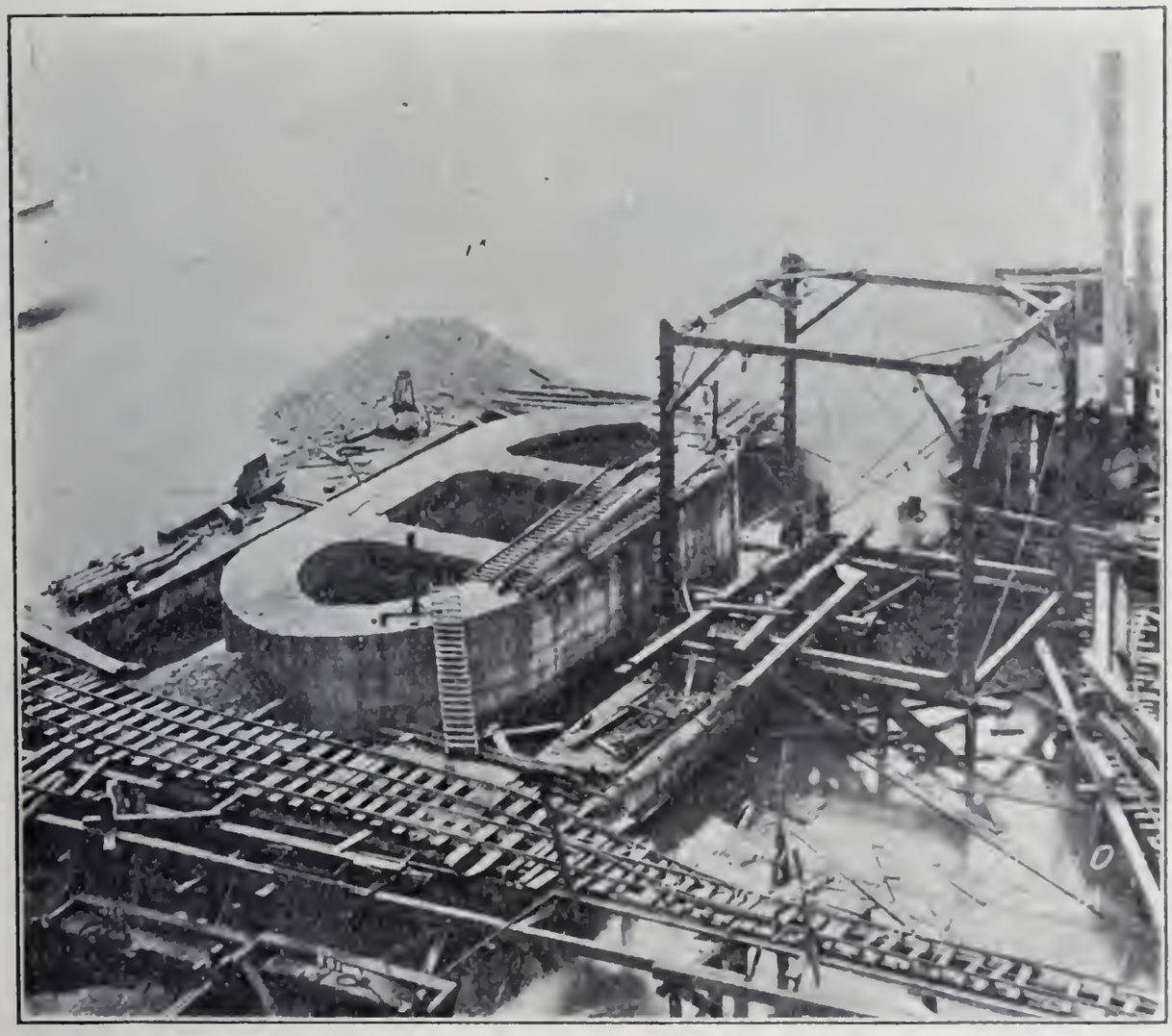

Fig. 6. View of Open Caisson, Pier No. 4, showing Working Chambers

to settle and thereby force the material at the cutting edge towards the center. The direction of the subsidence was entirely under control, the motion would be down at this end or that depending on the location of the deeper excavation in the interior, and when doing so would slightly change its direction. particularly so before it had penetrated less than half of its depth; after that the sides in contact with the gravel acted

more or less as guides. In this way the mass was easily controlled in its movement. The final locations of these caissons on the rock varied from the designed locations sidewise and lengthwise as follows:

	Sidewise	Lengthwise
No. 2	0.16 ft.	0.12 ft.
No. 3	0.15 ft.	0.85 ft.
No. 4	0.05 ft.	0.71 ft.

As the walls of these caissons were water-tight it followed that the difficulty in pumping the water from the working chambers at any desired time depended on the porosity of the material below the cutting edge. An attempt was made to fit the cutting edge to the slope of the rock surface. From the soundings it was known that the rock was not level; for this reason the cutting edge was constructed in a plane parallel with the surface of the rock while the top surface of the caisson was level.

Under favorable conditions it would be easily possible to sink caissons by this method, using comparatively sharp cutting edges, through water-bearing material into material impervious to water to a depth that would practically seal the interior from water from the outside, so that the working chambers could be pumped dry and filled with concrete without the use of compressed air. This was found to be not practicable at these piers, as the gravel was porous down to the rock and the rock surface was more or less irregular, as a consequence considerable pumping was necessary in order to lower the water enough to allow forms to be placed in the working chambers ten to twelve feet above the cutting edge for the purpose of allowing them to be filled with concrete to form the roof of the pneumatic chambers.

The usual pneumatic appliances were placed in the concrete; three locks being provided, one for men, one for excavating and one for lowering concrete, in addition to the necessary small pipes for air inlets, electric wires, water discharge lines, etc., as shown in Fig. 7. At this stage of the work the caisson was close enough to the rock to allow an accurate estimate to be made of the probable additional settlement that would be

accomplished by the use of air. From this information neat lines of masonry were defined on top of the caissons, and eight or ten feet of stone work were laid with concrete backing, to add to the weight to make sure that the direction of the resultant would be down and not up when the air pressure would be applied. The foundations were then completed in the usual

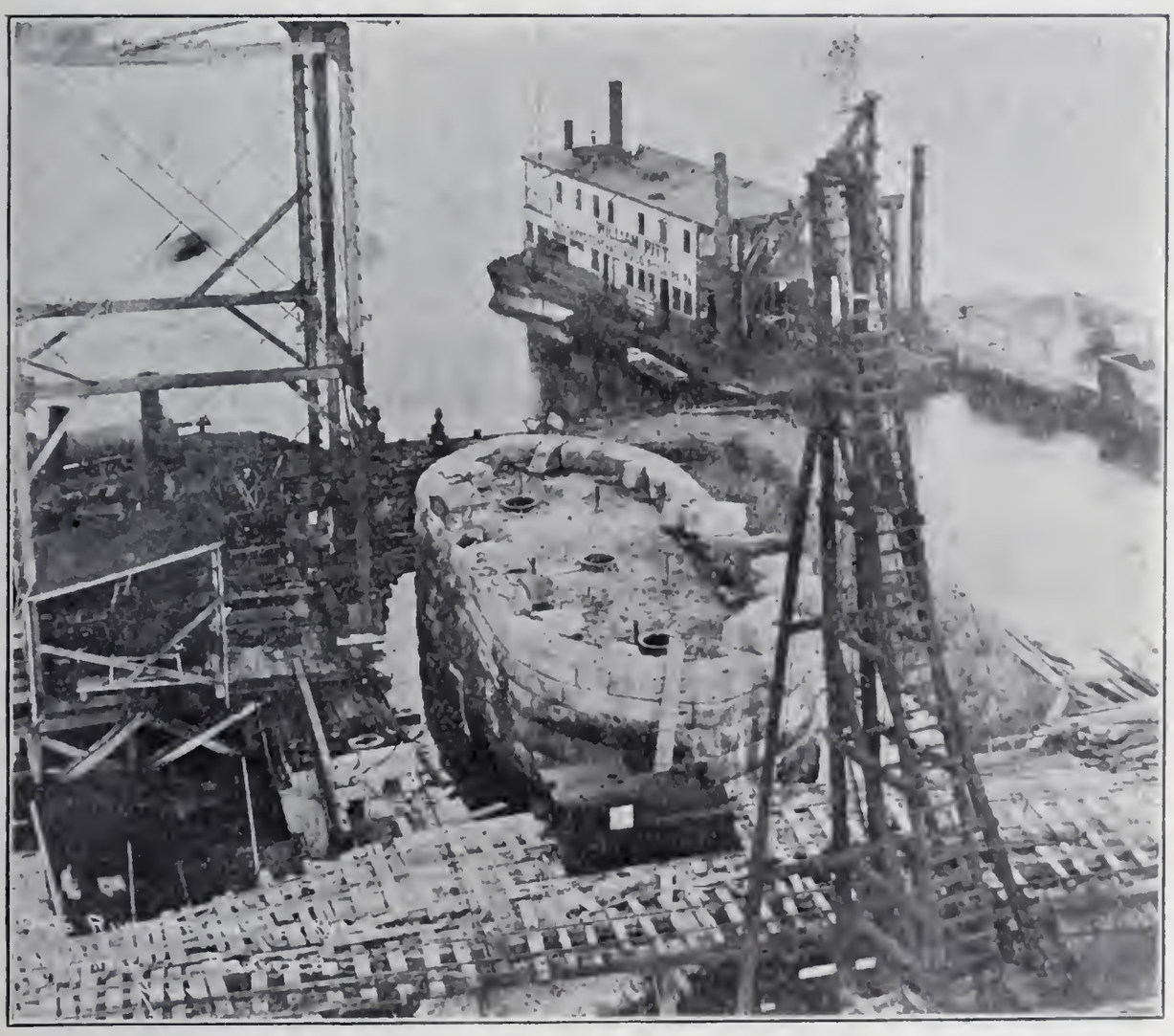

Fig. 7. View of Pier No. 4 ready for attachment of Pneumatic Locks

manner under air pressure; the balance of the material in the caisson was removed, the cutting edges were lowered through the projecting irregularities in the rock; the whole interior surface was cleaned, and washed, and completely filled with concrete from the rock to the top of the caisson and out well under the cutting edge, making a complete foundation, wholly

of concrete and steel from the rock up without a cavity or a single piece of timber in it.

ABUTMENT NO. 5

This abutment supports the shore end of the 370 ft. span. Top of rail elevation is 62 ft. above the ground surface and the drillings show 30 ft. of yellow sandy clay and 36 ft. of gravel to the rock. As at abutment No. 1 the size of the masonry necessary to make a stable structure, considering the 62 ft. of fill to be made around it, was so great that other methods than founding on the rock 68 ft. below the ground surface had to be considered. Wooden piles above the water line could not be used. The 30 ft. of sandy clay soil was not firm enough, unassisted, to support the loading without too much compression and settlement. The use of concrete piles seemed to be the easiest, satisfactory solution. The masonry designed for a uniform distribution over the base, under maximum loading in the same manner as in abutment No. 1, produced a loading of 35.5 tons per each of the 315 piles spaced 3 ft. by 3 ft. 3 in. center to center. The concrete piles are of the simplex style, 16 in. diameter, and are driven eight to ten feet into the gravel.

Before the pile work was commenced it was thought desirable to make some loading tests on piles driven similarly to those in the proposed foundation work. The first test consisted of a pile driven with four others around it spaced as in the foundation work, the four being driven while this test pile was still soft. The second test differed from the first only by allowing the test pile to partially set before the four piles around it were driven. The working conditions on a large foundation are such that the second test more nearly represents the actual conditions than the first. After both test piles were allowed 30 days to set the first pile supported a load of 60 tons for 72 hr. with 9/64 in. of settlement, which settlement it recovered almost wholly after the load was removed, while in the other case the results were as was to be expected, not good enough for approval. To meet the difficulty developed by the conditions of the second test, which is simply recognizing the well-known limitations of concrete and applicable to all kinds of concrete piles formed in

place, the following specifications were used, it is believed, for the first time on such work:

"The setting of the concrete in any pile must not under any consideration be disturbed by driving another pile or piles within a radius less than 9 ft. center to center, from it, after a minimum interval of 3 hr. or before the expiration of seven days from the time the concrete was mixed with water for that pile. The contractor may, however, at his own option drive pile forms within the nine feet radius to a depth not more than 3 ft. from the total estimated penetration, inside of the three hour limit; and then after the three hour limit and before the expiration of the seven day limit complete the driving and filling of these forms."

This specification was strictly observed, the piles were driven in rows across the foundation in the following order: Rows Nos. 1, 4, 7, 11, 15, then Nos. 2, 5, 8, 12 and 3, 6, 9, 13. After the piles were completed the earth was excavated a couple of feet below the cut-off line, and the concrete was filled in the usual way around and over the pile heads.

The construction of the embankment around this abutment some months after its completion caused a settlement of 1.25 in. vertically and uniformly.

The abutments and piers were built by contract, and the concrete piles were driven by contract, for the Pittsburgh and Lake Erie R. R. Co., J. A. Atwood, Chief Engineer.

DISCUSSION

Mr. R. T. McMaster*: The subject has been so ably covered by Mr. Raymer that it is hardly necessary to go into further detail. My chief duties on this work were to see that plans and specifications were carried out, and with the willing co-operation of the contractors this was a comparatively easy task.

We began the work about March, 1908, the lines giving location of piers and abutments having been previously given us. Of course we checked the distance between the points on each side of the river, to satisfy ourselves as to its accuracy, and found that we agreed almost exactly.

One of the interesting features in connection with our check triangulation was the measurement of the base line. We laid

* Engineer with The Pittsburgh & Lake Erie R. R. Co.

out a base line on the Monaca side of the river, on the up-stream side of the bridge site; the down-stream end of the line intersecting the center line of the bridge. The angles of the triangle were 97 deg. 20 min., 51 deg. 55 min. and 30 deg. 45 min. The base line was between the 97 deg. 20 min. and 51 deg. 55 min. angle points, and was 1001.103 ft. long on a 0.3 per cent. grade; stakes being set on line and grade every 25 ft. to support the 100 ft. chain used. This chain had been previously tested by the Bureau of Standards at Washington, D. C. Corrections being given for a 15 lb. pull, supported at 25 ft. intervals at a temperature of 62 deg. fahr.

We measured this line carefully three times early one morning before sun up, with a maximum variation of 0.003 ft.; the thermometer registering 61 deg. fahr. The careful measurement of this line at subsequent times under various conditions gave us results that confirmed the first measurement.

As the piers were constructed above the water line we located the center point of the piers from the lines established and turned the angle to the up-stream end of the base line, thus checking locations. When piers No. 2 and No. 3, which are on each side of the channel, 769 ft. span, were above the water line, we rigged a piano wire on a reel and used this to check the distance. We did this to make doubly sure that our tri angulation was correct. To get points on the wire we measured a distance of 769 ft. along the ends of the ties on the old bridge with our standard chain, nailing stakes on the ends of ties at 25 ft. intervals to support the chain. We then suspended the wire from each end of the 769 ft. line, drawing it to a 15 lb. tension. The wire was then covered with hot paraffin at the points of measurement. After the paraffin cooled we cut through it to the wire with a thread and tried to make a mark on the wire with nitric acid; not succeeding very well we mixed in a little muriatic acid and finally got marks on the wire at the points of measurement. We made the piano wire measurement on a cloudy day.

We then transferred the wire to piers No. 2 and No. 3, suspending it between these piers under the same conditions as

when marking it, and were pleased to find that we checked within 0.25 in. of the triangulation measurement. We then felt satisfied that we would come out all right.

When the contractor for the steel superstructure came on the ground he had the distances between centers of piers measured with a specially made tape, and checked the total distance to 1-16 in. We have great hopes that the superstructure will meet at the right point between the piers of the channel span.

Mr. J. J. Nolan:* There is very little to add. Mr. Raymer mentioned particularly the speed of the open caisson work, and I would like to call attention to the speed of the pneumatic work as well. After the caisson had been sunk to within 16 in. of rock and the concrete decks of the work chambers had been constructed, it was still necessary, in order to provide suitable foundations for the three piers, to excavate 250 cu. yd. of sand and gravel, 200 cu. yd. of rock, and to place 1800 cu. yd. of concrete by the pneumatic process. This, together with all incidental work thereto, was accomplished in 24 consecutive days, thereby establishing a noteworthy record for speed on work of this type and magniture.

Mr. J. H. Toupet: Referring to the concrete piles, were the piles in any given row driven consecutively, or was every second pile driven, necessitating going down the row a second time?

The Author: I shall be glad to explain that point. One pile can be driven close to another, providing the second pile is driven before the first one sets; otherwise the first pile will be damaged if the second is driven before the first one has fully set. The piles were driven continuously, each in its proper place, and if night overtook the workmen before they completed the first row, they drove two forms to a depth about three feet less than the total penetration and allowed them to stand over night. The next morning these two forms were driven to their full depths and the work was continued in the regular way.

*Engineer with the Dravo Contracting Company.

Mr. G. L. Taylor:* Our connection with the work is entirely with the steel superstructure, and I do not feel qualified to say anything on the subject of the substructure. The one thing that surprised me is the statement of the compression of the piers under the superimposed load. I would like to ask if that could not be accounted for in some degree by the settlement rather than the elastic compression of the piers.

The Author: We have not been able to satisfactorily account for this settlement in that way. The concrete was placed with extreme care on the rock, in and under the pneumatic caissons. All loose rock was removed. The solid rock was swept and washed, a fire hose being used on the surface until it was perfectly clean. Concrete was then placed on this perfectly solid foundation, and the working chamber in the caisson was filled solidly without a single void being left. The ducts or tubes leading from the exterior surface down to the pneumatic working chamber were also filled up to the top, and the piers were completed in the usual manner without any possibility of a void existing at any place. There is no timber in the caissons. It would, therefore, seem to me that the only way we can account for the settlement is by considering the compressibility of the materials, the two piers acting precisely alike under similar conditions of loading.

Mr. C. P. Buchanan: As to whether there was actual compression or only settlement of the piers, it occurs to me that Mr. Raymer's description rather indicates a compression. He spoke of the piers having gone down a very small fraction of an inch, with partial recovery after the load was removed. Would that not indicate that the concrete showed some compression under load? It seemed to me that it might possibly indicate that there was a compression in the concrete due to the superimposed load.

Mr. T. H. Johnson: Were the cutting edges of the caissons faced with metal, or were they finished in concrete alone?

*Assistant Chief Engineer, McClintic-Marshall Construction Company.

THE AUTHOR: The cutting edges were made of 8 by 8 angles, to which rods were attached, some being inclined inward, parallel with a sloping masonry surface, the others being nearly parallel with the outside vertical surface. In sinking the caissons by this method, the friction between them and the outside material increases with the depth. There was a possibility of the caissons being held in place by friction from the outside material, which condition would tend to rupture the structure as the excavation proceeded and the material was removed from the cutting edge. This possibility was anticipated by placing a sufficient number of reinforcing steel rods in the concrete to support the weight of at least the lower half of the caisson by tying it to the upper half. This contingency may have been a little remote, but should the caisson have been pulled apart it would have been very difficult to correct the trouble.

MR. J. P. LEAF: How was the rock surface smoothed up to give a good bearing for the caisson, and if there was any blasting done, what effect did it have?

THE AUTHOR: Very little blasting was done on the inside. Most of the irregularities were removed from under the cutting edge with picks and chisel points. The caissons were brought to a good bearing on the rock. The ultimate support did not depend on the knife edge bearing on the rock, as the concrete filling from the inside thoroughly surrounded the whole lower portion of the knife edge and extending outside of it where the material had been removed. An interesting fact was observed in the irregularities on the bottom of the river, 40 ft. below pool level showing water erosion on the rock. This, however, has geological rather than engineering interest.

MR. H. J. LEWIS: I was on the work several times and was very much interested in the thorough manner in which it was carried out. An interesting feature which was a factor in this work is the peculiar intersection of the Ohio and the Beaver rivers. If you look at the map you will find that a line down the Ohio river turns more naturally up the Beaver than it does

the lower Ohio below the Beaver. The Geological Survey explains this by saying that the upper Ohio ran into Lake Erie at one time, and that the Ohio came up stream from somewhere about New Martinsville. The gravel terrace on which Beaver is built was then a bar or the river bottom, and also the one in Rochester, which is somewhat higher than the Beaver terrace. When the river finally forced its way around to its present outlet, being thrust back by the glaciation and made the channel down the present Ohio, it left that kind of a Devil's elbow at the mouth of the Beaver, which has been more or less of a puzzle to navigators ever since and somewhat of a puzzle to the men who have tried to locate a bridge along there. So I think the engineering department of the Pittsburgh and Lake Erie R. R. ought to have much credit for working in a bridge at that point, which gives the navigator a show for his rights.

Mr. Edward Godfrey: I am glad to know that, in this case at least, concrete has been made water-tight. We read a great deal of the efforts made to waterproof concrete by using felt, tar, soap, wax, etc. A few years ago the government experts made numerous experiments on waterproofing concrete, and they found that a thickness of about thirty feet exhibited the properties of a sieve. Water flowed through their concrete in a stream. This was entirely due to the manner in which the concrete was made. When plenty of water is used in mixing, waterproofing compounds and layers of felt are superfluous. On some work I am familiar with in this city the reinforced concrete slabs were so dense that we had to drill holes through them to let the water out which was running down the walls.

Mr. W. F. Hall: Referring to the tests of the concrete piles. Although the concrete in one of the piles was somewhat damaged by driving the adjacent pile, I do not believe the same result would occur with all types of piles cast in the ground. In the system used at the Beaver bridge the soft concrete comes in direct contact with the soil, consequently there is a certain risk when the second pile is driven, of causing a deformation, shearing, or cracking of the first pile due to compression in the ground, or the jarring from the hammer.

In the system of piling where a tapering sheet steel shell is driven by means of a collapsible core, which core is subsequently withdrawn, the concrete placed within this shell remains there a unit mass. An injury to such a pile cannot take place nor harm result to the setting concrete, as did occur to the pile tested at Beaver.

The wave motion set up in the ground while the hammering is going on will, in my opinion, pass around the shell pile, jarring the whole pile as a unit and, if anything, producing a denser concrete which is a good reason for continuous work.

THE AUTHOR: I do not wish to enter into a discussion at this time in regard to the merits of the different kinds of concrete piles. I believe it desirable, however, to call attention to the fact that it was not the deformation of the pile that I referred to, but the more serious interference with the strength of a concrete pile by jarring it to the extent of breaking the concrete while it is in a defenseless condition, which condition exists after the concrete has commenced to set, and continues until it becomes hard enough to defend itself. After the piles were tested they were removed by excavating around them. The pile which stood the 60-ton test satisfactorily was still soft while the surrounding piles were driven. It was found to have a full section and was beautifully shaped throughout. The other pile failed because of the limitations of the concrete, which limitations are equally applicable to all kinds of piles formed in place.

MR. V. R. COVELL: I desire to have one other point made clear: Are the anchor wells to be left open permanently or will they be finally closed?

THE AUTHOR: This is a very interesting subject and will be more fully discussed in connection with the description of the superstructure. The anchor bars consist of 8 *I*-bars, 14 in. wide by 1¼ in. thick under the end of each truss, extending 50 ft. into the masonry at abutment No. 1, and 65 ft. at pier No. 4. The elongation of these bars under their maximum stress is quite appreciable, so much so that it was decided not

to fill around them until they were under their maximum stress. The design of the superstructure is such that maximum stress is maintained in these bars permanently. The bars under the maximum uplift are held under maximum stress by a wedge being driven between the pin at the upper ends of the *I*-bars and the masonry. The openings around the anchor bars will be completely filled after the completion of the superstructure. The wedges will be placed when the creeper traveler is at its extreme distance from the channel pier.

Mr. H. S. Prichard: In sinking the piers a notable feature was the great quantity of subterranean water encountered. Quantative information on this subject would be interesting.

Mr. L. P. Blum: Mr. Raymer brought out the fact that the variation from the theoretical position of the pier was about ten times greater longitudinally than laterally. What occasioned this?

Mr. R. T. McMaster: The only reason for that is that they lowered one end too far before starting at the other end. It was convenient to continue the work as long as possible at one end, lowering it quite a distance, and then drop the other end. Sideways, they had little difficulty of this kind because the excavation was nearer the center.

FLOODS IN THE RIVER SEINE

REMARKS ON PROPOSED MEANS TO MITIGATE FLOOD CONDITIONS AT PARIS

By Thomas P. Roberts*

PECULIAR SOIL CONDITIONS IN THE SEINE BASIN TENDING USUALLY TO RESTRAIN FLOODS BUT OCCASIONALLY TENDING TO PROLONG AND INCREASE THE VOLUME OF THEIR DISCHARGE.

There are some peculiar and interesting features in the valley of the Seine above Paris with reference to floods, which appear to be worthy of a more careful study than the writer has been able to give them. While the facts regarding the mean, low and high water discharges of the river at Paris are matters of record, many American engineers will be surprised to know how radically different the figures are as compared with the discharges of American rivers from areas equal to that of the Seine basin above Paris, especially if the comparison be made with streams in Western Pennsylvania, West Virginia, Ohio, or Kentucky.

It is true that the mean annual precipitation over these American districts is considerably greater than that over the Seine valley. It is worth remembering, however, that it is the eccentricities of precipitation that have most to do with river floods, as well as of low water conditions. We may have disastrous floods in our Western rivers during years of low mean rainfall and, contrariwise, no very great floods during years of extremely high mean precipitation. The same thing doubtless holds for the Seine valley, for, notwithstanding its general low mean precipitation, there come times of protracted storms of snow or rain driven by gales from the Atlantic which cover all of northern France and the adjacent regions, little retarded

* U. S. Engineer Office, Pittsburgh, Pa.

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by the Vosges Mountains, but breaking up furiously on the flanks and in the valleys of the Alps, as a rule doing more mischief along the Saone and Rhone rivers than they do in the region drained by the Seine.

It never occurs on the Seine that its flood discharge per second, no matter what the rainfall may be, is as great as is experienced on our American streams of equal drainage areas.

Special attention will be given in what follows to natural soil conditions of watersheds, as tending to influence their high, low, and mean discharge. From a consideration of this point may be explained some of the erroneous ideas reached by flood theorists, for it may be shown that the opinions of persons familiar only with their local surroundings are of no account for regions where the soil conditions may be radically different.

The writer disclaims any desire of inflicting upon his readers even a synopsis of the pros and cons of the forest and flood question, but will refer those still in doubt as to the merits of the controversy to the papers of Col. H. M. Chittenden[1] and Major W. W. Harts,[2] of the Corps of Engineers, U. S. Army. and to the recent report of Mr. Willis L. Moore. Chief of the Weather Bureau, to the House of Representatives Committee on Agriculture. The writer may be pardoned for directing the readers' attention also to a paper of his own, in this connection, written at the request of the American Forestry Association and published in the Proceedings of the Boston Meeting of the Association September, 1885.[3] Just because records produced by the engineers, both in this country and in Europe, run amuck with the theories of the foresters, the engineers have been much in disfavor, misunderstood, and misinterpreted in the "Conventions" and in the popular magazines. However, the engineers believe their "headlights" are now penetrating the fog more and more as the months roll by, and hope soon to have a clear track ahead.

1 Trans. Am. Soc. C. E. Vol. 62. p. 244.

2 Trans. Am. Soc. C. E. Vol. 62. p. 347.

3 This paper is largely contained in a paper read before the Engineers' Society of Western Pennsylvania and published in the Proceedings of the Society Vol. 2. p. 285.

The valley of the Seine above Paris embraces about 15 000 sq. mi., or approximately slightly more than twice the area of the Monongahela watershed above Pittsburgh. The greatest measured discharge at flood stages previous to the recent flood at Paris known to the writer was 58 600 cu. ft. per sec., occurring in 1876. (The gauge reading was not given). The same authority placed the greatest known discharge of the entire river below a drainage from 30 000 sq. mi. at about 90 000 cu. ft. per sec.

It is remarkable that intelligent European writers should have ignored, as so many of them have done, the possibility of a repetition of old-time floods of the Seine. Sewer engineers, subway engineers, architects and artists all appear to have forgotten the floods which had occurred so many generations before their time. We in America are apt to consider our century old experience of floods amply sufficient and plan our bridges and other works according to that experience. We speak of the "unprecedented" without the slightest knowledge of what happened in the 16th and 17th centuries, and with but very scant information indeed even of what may have happened in the 18th century on our Western rivers.

The usual low water discharge at Paris is given as 2650 cu. ft., and after protracted drought occasionally reaching as low a figure as 1200 cu. ft. per sec. For the Monongahela basin of half the area of the Seine valley above Paris floods discharging 160 000 cu. ft. per sec. are not unusual. The 160 000 ft discharge may be taken for comparison with average so-called high floods at Paris. Undoubtedly the late flood must have greatly exceeded 58 600 second-feet, perhaps reaching, and possibly somewhat exceeding, 100 000 cu. ft. per sec. Dispatches from Paris several times gave the velocity of the Seine during the late flood as 25 mi. per hr., which is absurd on its face, as the old arch bridges would have been swept out and their integral stones ground to boulders and pebbles and pushed into the Atlantic with any such current. Such a current also would have undoubtedly scoured the river down to its chalk rock bed.

The table below gives some figures of discharge for the Seine compared with two American streams:

RIVERS	Area of basin sq. mi.	Cu. ft. per sec.			Discharge sec. ft. per sq. mile of water shed		
		Approx. high water	Usual low water	Ext'me low water	High water	Usual low water	Ext'me low water
Seine above Paris.....	15 000	60 000	2640	1200	4.00	0.176	0.080
Monongahela above Pittsburgh.....	Approx. 7 391	160 000	400	175	21.65	0.054	0.024
Ohio at Pittsburgh.....	18 644	350 000	2500	1400	18.77	0.134	0.075

NOTE.—In March, 1907, the Monongahela reached a discharge of 230 000 cu. ft. and the Ohio at Pittsburgh 430 000 cu. ft. per sec.

It appears from the figures that from equal areas the flood discharge of the Monongahela is more than five times that of the Seine, while, contrariwise, the Seine's low water discharge is more than three times that of the Monongahela, and its extreme low water discharge about four times that of the American river. The Ohio is more nearly like the Seine at low water on account of the very considerable volume of ground water stored in the glacial drift regions traversed by some of the tributaries of the Allegheny River, the parent stream at Pittsburgh of the Ohio. The effect of ground storage on the Ohio diminishes in descending the river to Cairo, as most of its large tributaries have characteristics resembling that of the Monongahela as to soil, slope, seasonal rainfall and temperature. The ratio of discharge to annual rainfall for the Ohio at Pittsburgh is about 60 per cent., while for the entire river at Cairo it is only about 30 per cent.

It is to be noted that if the entire Seine valley were taken into consideration the regularity of its discharge as compared with American rivers would be much more manifest and still more so, if such tributaries of the Seine, as the Oise and Marne could be placed in juxtaposition with similar tributary areas of

the Ohio.[4] It is regretted by the writer that for present lack of data he is unable to make the comparisons indicated.

For convenient reference a table of the principal floods of the Seine at Paris from Egault (1814) and other, later, French engineers, compiled by Mr. Willis L. Moore, excepting the recent flood, is presented in this place:

Dates of the Inundations	Height at the bridge of La Tournelle	Mean per half century
	Feet	Feet
July 11, 1615	29.99	27.53
January, 1649	25.10	
January, 1651	25.59	26.36
March 1, 1658	28.87	
March, 1690	24.61	
March, 1711	24.77	25.34
December 25, 1740	25.92	
January, 1751	21.98	22.42
November 14, 1764	22.97	
March 4, 1784	21.85	
February 4, 1799	22.87	
January 3, 1802	24.44	21.22
†March 3, 1807	21.85	
May, 1836	18.66	
February, 1850	19.91	
*January 29, 1910	27.90	

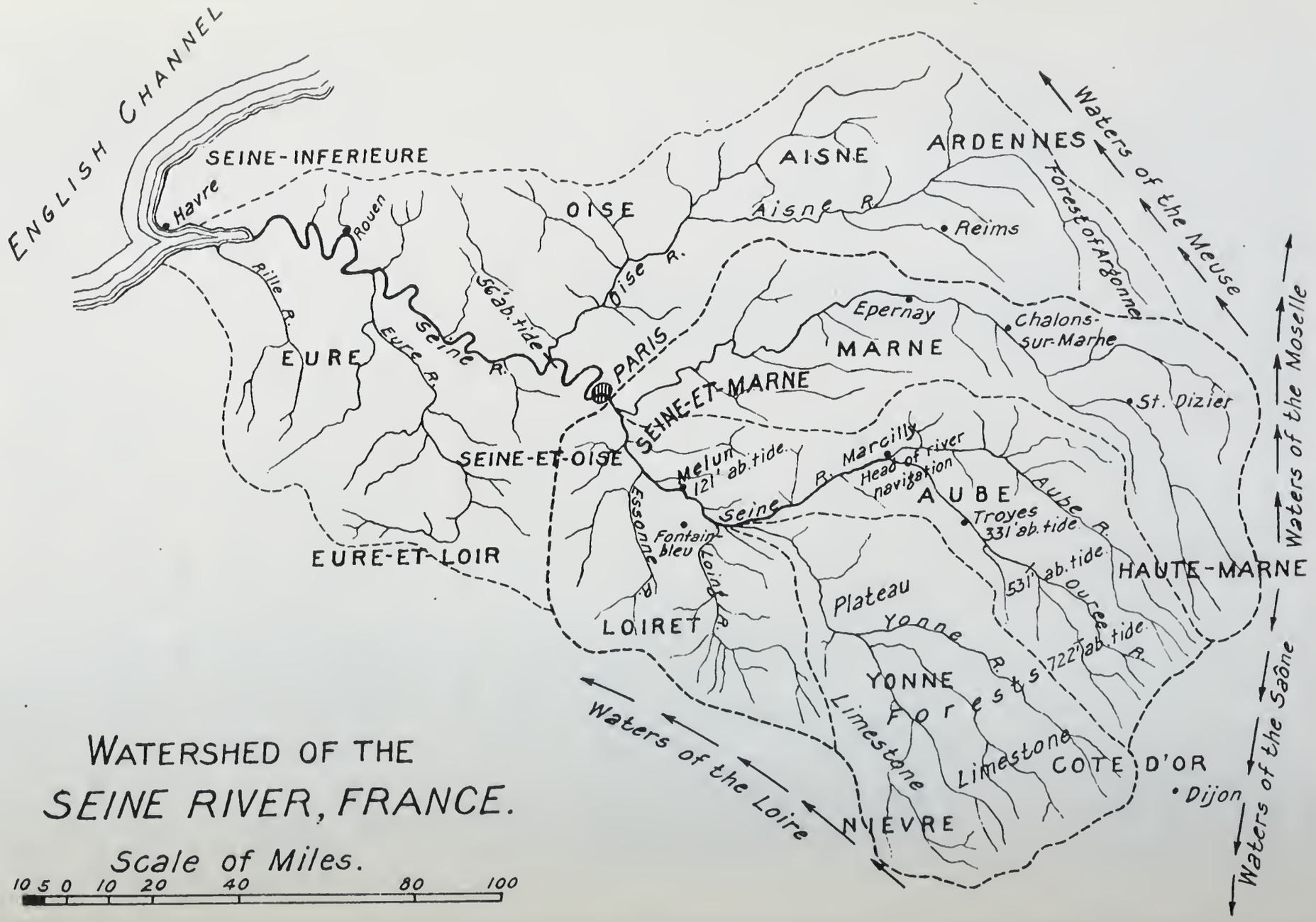
† From "La Nature," Paris, February 5, 1910. March 18, 1807, River still high, 21.3 ft.

* From "La Nature," Paris, February 5, 1910.

SOIL OF THE BASIN OF THE SEINE

Three-fourths of the basin of the Seine is said by a Brit. Enc. writer to have a permeable soil mostly chalk, which chalk extends from the coast to points considerably east of Paris. Farther east towards the headwaters, especially in the Department of Marne, there are extensive areas of sand and gravel soils, and about the heads of the Yonne and the Ouree branches

4 A late English authority states that a few days before the recent flood at Paris reached its maximum height the Marne rose to a very high point with an unusually swift current. At this time the Yonne was very high due to the rapid melting of snow accompanied by rain on the Morvan plateau. The remark as to the Marne indicates that there must be considerable areas of its water shed of only medium retentiveness and that it became surcharged during the five days of almost continuous rains January 22 to 26. The details of rainfall have not yet been published.



WATERSHED OF THE SEINE RIVER, FRANCE.

Scale of Miles.

10 5 0 10 20 40 80 100

of the upper Seine there are extensive exposures of limestone, where, in places, rain water rapidly sinks to reappear in springs.

The "Statistique Generale" of France in its description of the soil of the country gives to chalk and limestone 37 793 sq. mi., to gravel 13 196 sq. mi., to sandy soil 22 863 sq. mi., making a total of 73 852 sq. mi., or just about one-third of the total area of France. One-half or more of the permeable soil is found in northern France, and of this perhaps 22 000 sq. mi. is embraced in the basin of the Seine. For the area of permeable soil above Paris no accurate information is at hand, but it may be gleaned from descriptions of agricultural operations in the several Departments that perhaps rather more than two-thirds of the country has a permeable soil.

It is altogether due to soil conditions that such a countless number of springs exist in the Seine valley and in the champagne country of Aube and Marne, to say nothing of the limestone districts where there are some notably large springs.

We have examples of marked permeable soils in this country east of the Mississippi River. Thus the Cumberland valley of eastern Pennsylvania, of limestone formation, where in an area of about 600 sq. mi. there are practically no water courses save those issuing from six well-distributed springs of remarkably large and very equable discharge, one of them being the third largest spring in the United States. In the glacial belt of northern Ohio and Indiana and southern Michigan there are areas where even four inches or more of rainfall in 24 hours shows an exceedingly small immediate effect on the streams, floods being impossible unless the rain falls on a frozen surface; but as the region in question is usually overlaid with heavy snow all winter, the soil beneath is rarely frozen. The Marne, the tributary of largest drainage area above Paris, the Oise, entering the Seine a few miles below the city, also the Eure and some other smaller tributaries are noted for their *regular discharge*, that is to say, their freedom from considerable floods as well as from very low water conditions, although in the case of the Eure basin, as pointed out by the French engineer, M. St. Clair, and referred to by Mr. Moore, agricul-

tural operations on the steep slopes of its headwaters in the nature of irrigation may have some effect in diminishing its low water discharge.

The *irregular,* or Seine tributaries above Paris noted for their extremes of floods and droughts, are the Yonne and streams from the Departments of Nievre and Cote d'Or, and to a lesser extent streams from portions of the Departments of Aube and Haute Marne. It so happens that these streams most subject to floods and droughts are those draining the most heavily forested districts of the watershed, while, contrariwise, the Marne valley and the "chalk" and champagne districts, where there are neither very high nor very low river stages, until within the last two decades are spoken of as practically treeless.

The foresters and the engineers of northern France had their little war more than a quarter of a century ago. The writer recalls how Herrich, an engineer, attributed the gradually diminishing height of the great Seine floods, 1615 to 1880, when he wrote, to deforestation. His American brethren of the present generation never have questioned Herrich's records, but as they blame the floods on the rains and not on the trees, they are rather indifferent as to what may be placed on the ground,—be it trees or agricultural crops. The "War" in France of late years has been transferred to the Rhone valley, where chalk, sand, gravel, and limestone are not so much in evidence to confound the theories pro and con.

If it be assumed that two-thirds of the Seine valley above Paris has a permeable soil which holds back floods to a great extent we are in a position perhaps to understand the *raison d'etre* of the Paris floods.

The permeable soil gives rise to springs and, in special cases, to a large ratio of annual discharge to downfall of rain. While the Marne and the other "equable" tributaries of the Seine draining two-thirds of the basin may never reach great flood stages, they are nevertheless capable in the aggregate of keeping up a long protracted medium flood stage at Paris. It is affirmed, for instance, that during the flood of 1876 for *fifty-five days* the river at Paris was nearly all the time high, en-

dangering property on the quays. They appear in Paris to be having at the present time a repetition of the same thing, for at this writing about three weeks after the river began to fall from its highest point, it is still almost 18 ft. above low water mark. Again, in 1807, according to a recent statement in *La Nature,* high water must have been maintained at Paris for several weeks. We have nothing of this sort in America on any river east of the Mississippi below so limited an area as that above Paris. Usually the floods in America have passed and the streams are well below the danger line in a few days after the storm.

SUGGESTIONS AS TO AMELIORATING FLOOD CONDITIONS AT PARIS

The Seine below Melun, past Paris, to the sea has such a light slope as to produce only gentle currents, and hence the water cannot get away as speedily as it does on most of our rivers. This sluggishness of the current necessarily greatly increases the difficulties to be overcome in devising means for lessening the damages from floods at Paris. It would appear that largely from the springs of France, which make canal and river improvements practicable and easy to maintain over the northern Departments, there arises at long intervals the possibility of a very serious disaster in the Seine valley.

During the weeks of high water, to which the chalk, champagne country may furnish a large and very persistent volume, a second rain storm may traverse the Yonne, Nievre, and Cote d'Or, the elevated wooded regions. It may not be a very great rain fall, but it furnishes a sudden and sufficient increment from the bad third of the basin, which on top of the medium flood at Paris may perhaps bring about serious conditions.

French engineers long ago condemned storage reservoirs for mitigating floods in their own country because they feared there might arise the case of overflowing reservoirs in one part of the valley, passing out water which without reservoirs would have reached the sea, thus adding to the effects of a secondary flood from another region in the valley above. Nature is now illustrating at Paris one of these possible mishaps attending the

use of reservoirs. The chalk and gravel beds, splendid reservoirs in the Marne and Seine valleys, are letting out too much water which cannot be controlled; for it is probably the case that few sites, owing to the character of the soil and to the topography, can be found for very large artificial reservoirs.

No reservoirs have so far been considered in France, the writer understands, proposed to serve water-power projects as well as to restrain floods, such as have been recommended in this country by some advocates of "Conservation." The French engineers for the most part believe that flood reservoirs, if they are to be built at all, should be kept empty as long as possible so that their maximum capacity may be available when the "cloud burst" storm arrives. Fortunate it is indeed for the Parisians that the very great floods come, apparently like some of the comets, after intervals of centuries; but there is danger to the subways and to the large sewers, i. e., to underground Paris, from the second, and even from the third, grade of floods which are apt to reach the city at intervals of 50 and 20 years, respectively. The engineers, apparently, did not plan even for these minor grades of floods.

The problem remains: What can be done to mitigate the situation at Paris? Are sites available in the one-third, or bad region, above Paris for reservoirs of sufficient capacity to hold off the crests of threatening floods? Perhaps there is hope for some betterment in that direction. As for tree planting, as advocated by the foresters, it is being done to some extent, but it is to be feared trees cannot prevent water sinking in the permeable soil and feeding the springs. American foresters with almost one voice argue that trees increase the discharge of springs, which, if true, is the very thing the Frenchmen do not want.

Projects looking to the enlargement and shortening of the Seine from Paris to the sea must involve vast expenditures. It is not so much extra width of channelway that is needed, in the writer's opinion, as means to increase the velocity of the current, which can probably best be secured by deepening the existing channel. Possibly more good can be accomplished by such method than by attempting to straighten the main stream

and saving 20 mi. by a new course, only 15 mi. long, which is one of the "map possibilities." Surveys would be required to develop sufficient facts before opinions worthy of serious consideration can be formulated. It is clear, however, that any new course for the river should be considerably deeper than the old course to accomplish much good, for after all a shallow new course would form only an additional pond, which would soon be filled. The lowering of the stream bed in any event is imperatively demanded to lower the flood surface of the river. The river at Paris averages only about 450 ft. width at most of the bridges. If it were a very swift river it would be advantageous to remove the bridge piers as much as possible, but with slow currents they do not enter as an important factor as obstructions increasing the height of floods to any marked extent. The photographs of some of these bridges during the height of the flood indicates little necessity for their removal or alteration.

Budapest, on the Danube in Hungary, where indeed there is a mighty river, remedied the difficulty of having its business section submerged by floods caused by ice gorges in the river by raising the streets and buildings well above the high flood level. Paris might adopt the same means and do the work gradually; but in any event, and no matter what project may be considered, great difficulties will arise, enough almost to distract the boldest engineers. To raise a city with such remarkable historical associations, with its works of art and structures of almost incalculable value, would seem to be a proposition of an iconoclast rather than of an engineer. All the world looks on and awaits with interest the conclusions of the Parisians. They will be wise in taking plenty of time to make up their minds.

DISCUSSION

Mr. Morris Knowles: Mr. President, I do not know that I have anything in particular to say, as I do not know the facts about the Paris floods and therefore cannot discuss the subject intelligently. But to respond to your request, in a slight degree, I think the Society owes a debt to Col. Roberts

for stepping so admirably into the breach, in the absence of the regular speaker for the evening, and I think we are particularly fortunate, in that he is so close in touch with this subject as to have the information at hand and can tell us about it.

I believe one thought which we can draw from the paper is this, that it shows very thoroughly the danger in drawing conclusions too quickly and from inadequate data. As the author says, we have from time to time been face to face with the fact that every once in a while we find something unprecedented; but by careful study—or perhaps the study does not reveal it because we do not know all that occurs,—we find some of the same things happened many centuries ago. America is young and therefore it does seem foolish to draw too many hasty conclusions.

In Europe they have records running back a considerable length of time, but it is a question whether the data, the factors going to make up those records, is wholly known. It may be that much of the data is indeterminate. The height of floods and the extent of floods depends upon many many factors; we are most interested to know first the amount of rainfall, but there are many others, such as the season, the frequency, the intensity, the distribution of the rainfall over the various parts of the watershed and the character of the portion of the watershed upon which it falls; so that we cannot and should not draw conclusions too hastily, even from the very oldest of records.

I was struck with one statement in the paper, namely, that engineers are apparently "coming to their own," to paraphrase what the author stated, in this controversy between "the forests are good" and "the forests are useless." For a period he says they were not so thoroughly respected and their opinions were not so highly regarded, but now it is different. I presume he refers to the engineers who believe conservation has nothing to do with floods. The trouble with some engineers, and in fact with many others, has been and still is in drawing conclusions from records too meager and extending over too short a time and thus trying to prove a preconceived opinion Some are too ready to take the flood records as we have seen them in the last fifty years or less and say if they have increased

or decreased in number or intensity that proves or disproves the particular claim being advanced.

I am inclined to think the last word has not been said and, while apparently to some, the pendulum may seem to be swinging to the position that the forests and other conservation methods upon watersheds for the amelioration of floods are not successful; I take it, however, that almost all this argument is based upon one thing, simply that records of floods and forests areas do not show it. The reason why some records do not show this is that we do not know what the records are. If we had the records of many centuries and all the detail data of the many contributing conditions, necessary to draw proper conclusions, we would know something more and undoubtedly find the facts are as our common sense teaches.

The general conclusions based upon the usual knowledge of people are worth something. Certain truths have been handed down to us from antiquity, the fact that vegetation and forests in the Holy Land and near the Pyrenees and in the north of Italy and China are not what they used to be centuries ago and now that they are arid and eroded wastes, subject to frequent inundations, certainly teaches some lesson. This should indicate to us that there is some additional information of which we have lost sight, and so I believe that the last word has not been said and may not be said in our generation. If we had the complete records we would have the story. Let us do all we can to see that complete records are preserved, so that the generations to come may draw accurate conclusions.

Mr. R. A. Cummings: The speaker has been impressed with this very instructive description. Among the statements, although inadvertently made, was one that can be applied to the traffic on the local rivers and to the low bridges. Although the bridges over the Seine are low, river traffic is said to be undisturbed, because the velocity of the current is small and the vessels are made to conform to the conditions. Similarly it seems to me that the agitation here about raising the low river bridges is unwarranted as it does not disturb the traffic during normal conditions of slack water in the Pittsburgh Harbor. Again,

there is danger from ice, drift and high velocity of flow in navigating the rivers during the extremes of the winter floods.

The speaker has much satisfaction in finding that so competent an authority as Col. Roberts has concurred in his suggestion, to dredge the submerged dams for reducing the flood level, contained in his discussion of a recent paper before this Society.

The whole subject of floods and protection against them is circumscribed with varied factors. It is quite certain that much data and information will be brought out from the recent floods in the North of France. It has occurred to the speaker that possibly they may be attributed to a frozen condition of the soil within the entire watershed and an exceptionally heavy and continued fall of rain throughout the area and especially near the headwaters.

Whatever the cause, a careful study and analysis for the controlling factors must be combined with mature judgment if we are to profit by the experience of the French floods.

Mr. J. N. Chester: It is disappointing to hear such an eminent authority as Col. Roberts state that straightening out the Seine below Paris would not increase its carrying capacity, for as we recollect the map that he had thrown upon the screen, a straight line from Paris to the sea would not exceed one-half the present length of the Seine, and casting aside our own experience and consulting only the popular formula for flow of rivers, which is

$$Quantity = C \sqrt{R \times S}$$

in which S as a factor or a multiplier represents the slope for given distance, and it will be thus seen that the straightening of the stream would double the slope, and therefore increase the flow as the square root of twice the original slope or approximately 25 per cent.

There would also be a material gain by the reduction of the friction, for a much smaller co-efficient C would appear in the formula for a straight line than would necessarily appear in the formula of the river as it now winds and turns on its road to the sea, and I do not hesitate to venture the opinion, although directly contraverting Col. Roberts' statement, that the

straightening of the Seine would increase its flow over 50 per cent.

We wish, however, to make a harsh criticism just and must therefore consider a well grounded theory that a crooked river such as the Seine if but partially straightened and thus shortened will again lengthen by spending the increased energy, due to the shortening and increased fall, against its first diversion from a straight line, so that unless the river were straightened for its entire distance or at least where straightening was attempted at all, that it should be continued to a point in the channel where the present course ran for some miles in a straighton direction and where the accumulated velocity might be somewhat lessened by the flow through a straight channel of the original gradings, it would again assume its original length.

The writer has come into possession of knowledge of the above by dearly bought experience on some of our Southern Rivers and considering the Colonel's extended experience, we can scarcely believe that he intended to convey what we believe he has on the most of his hearers, but rather that the statement was ungarded and not meant in the light it was apparently made.

President E. K. Morse: If ther is no further discussion of the subject or any questions any member would like to ask the Speaker, I would like to make an explanation giving the reasons why no flood came out of the Allegheny River this Spring. When the recent warm weather came and there was great apprehension that the accumulation of snow in the headwaters of the Allegheny River, which, if melted, would make not less than six inches of rain water, would give us a disastrous flood. The Weather Bureau evidently did not properly consider the condition of the ground and the snow. The snow level at the time, March 1st, was about three feet on the level, and at many points had drifted badly. We had previously experienced three decided thaws which had practically taken all the snow off the ground in the immediate vicinity of Pittsburgh, but had only the effect of packing the snow at the headwaters of the Allegheny River to the condition of snow ice, and at no time was the

thaw sufficient to get any of the melted snow into the creeks, but each time is had frozen hard just before that point had been reached. The snow which first fell on December 24th, after the ground had frozen considerably, formed a blanket which was sufficient to draw out all of the frost. This condition, coupled with the further fact that as rain fell and the snow and ice melted, it percolated through this thick coating to the ground below, and what was not absorbed was held back and the flow made uniform, accounts for what the Speaker has stated as being an almost unprecedented condition of uniform stage in the river for days, just below the danger line. It seems impossible for anyone to deny that the snow held the water back and let it into the streams uniformly, and if this cannot be successfully denied, does it not prove that the leaves, humus, brush, etc., in fact our forests, holds back the heavy rain fall, thereby distributing the rain fall either in water going direct into the river or later by ground flow, just what this snow blanket has done recently? There is one other condition that emphasizes this point; it not only rained in this vicinity and to a large extent in the headwaters day and night for several days, thawed continually day and night, and, in fact, on my thermometer the temperature never registered below 40 deg. any night for eight days, thereby emphasizing the importance of such a blanket of snow ice in retarding the rapidly melting snow and ice and increasing the ground absorption to perhaps 60 or 70 per cent. of the melted snow and rain, and clinching the argument for reforestration and its effects.

THE AUTHOR: Something as to the salient features of the remarks of my fellow members may be in order in closing the discussion. I quite agree with Mr. Knowles when he said at the close of his remarks, "the last word on the forest and flood question has not been said and may not be said in our generation." I had thought he was almost over on the "right side" from the kindly tone of his introductory remarks, but his mind reverted to Italy, Spain, the Holy Land, and China, where arid, or semi-arid regions exist, subject to erosion, etc., where formerly, it is said, the country was fruitful and populous. In regard

to the Holy Land, and also Mesopotamia, I know of no writer who has more faithfully depicted their climates and soil conditions than Prof. Socin, of Tubingen University. He affirms that it is quite possible to cover even greater areas with irrigation canals about Babylon, etc., than were ever cultivated by the ancients with their canals. He says in effect that lands adjoining the vast irrigable plains, too high to be reached with the water, always were arid, or semi-arid, capable of supporting only migratory tribes, who, with their asses and camels and "much cattle" followed the short lived grass crops from place to place, just as they did in Abraham's time, and just as they do today. An English company has proposed to extend a railway from the Mediterranean Sea to the country between the Tigris and Euphrates rivers and there reconstruct the ancient canals. Nothing delays the work it has been recently stated, but doubt as to the ability of the Ottoman government to control the Arab tribes.

As for Spain, much the greater portion of the country is today exactly as it was when the Romans and the Moors were in possession, viz., only productive where it could be irrigated. About 5000 sq. mi. of central and southern Spain is under irrigation today. In Morocco, where the Romans had delightful health resorts and extensive market gardens, can be found the remains of the irrigation ditches, which were abandoned only when the nomads drove the Romans out.

The modern traveler through such deserted and barren regions is apt to imagine that the climate has changed, and as he sees no trees, jump to the conclusion that it was the destruction of forests which caused the woeful change. In such semi-arid regions forests could only be maintained by irrigation. Seasonable rains are necessary for tree life in a state of nature.

There appear, however, to be exceptions to the rule of fixity of climates. Thus in Central Asia, east of the Caspain Sea, a traveler whose name I cannot at present recall, describes a region where only the remains of dead forests can be found. He reached the conclusion from the evidence of dried up lakes, supported by traditions of the natives, that at long periods of time, with centuries intervening, something happens to change

the climate and that in time new forests will arise, and the camel trails will, as they have several times done during the past thousand years, wind around the borders of the restored lakes as of yore.

Or, take the experience of the 11th century A. D., when, for seven consecutive years there was no flood on the Nile. How long must we wait for such another drougth in Africa? For a preceding drouth, about 1600 B. C., see Genesis Chap. 41 : v. 53, et. seq. It is such things as this which give warrant to Mr. Knowles dictum,—that it will be a long time until the final word is said about forests and floods.

To Mr. Cummings' query as to whether the surface of the country above Paris was frozen prior to the recent flood will say that while I was at first impressed with the possibility of such a thing, after consulting the temperature records sent daily from Paris to the U. S. Weather Bureau, I discovered no evidence sufficient to warrant the assumption that a frozen surface was much of a factor in the case.

As to Mr. Chester's statement in his opening sentence, that I said in my paper "that straightening out the Seine below Paris would not increase its carrying capacity," I think I said nothing to warrant such an idea. Perhaps my language was not as full or definite as it should have been. I was pleased to hear Mr. Chester continue with his observations on the effect of shortening streams in increasing their discharging capacity, but will remind the Society that as the Seine runs through the best part of Paris for a number of miles, I cannot see how very much good can be accomplished in lowering the height of floods, by a cut-off which must start far below the city. Deepening the river bed at least through the city down to such proposed cut-off would seem to be demanded. Such a cut-off should be made for flood purposes only, leaving that old channel with its valuable locks for ordinary uses as heretofore. As stated in the paper, however, we can afford to wait for engineering data before seriously discussing projects.

President Morse' remarks were of great interest and permanent value especially as they relate to the depth and nature of the snow which recently covered the Allegheny valley. Of

course no one can deny for a moment that the snow melted very gradually, but most assuredly the portion that daily becomes fluid must have speedily reached the water courses. What was "held back" by the snow or ice, was snow or ice, or water only in its potential form; and therefore I fail to perceive the analogy between the snow that remained on the ground and leaves, humas, brush, etc., which can hold more or less water. If Mr. Morse is correct, we are to regard deep snows over our upper valleys as preventive of floods rather than sources of danger. Sometimes they may be preventive and sometimes they may not. The greatest known general flood in the Ohio in 1884, was on all sides credited more to the melting of the snow, which covered about 60 000 sq. mi. of the valley above Cincinnati, than to the rain fall.

President Morse' last statement "emphasizing the importance of such a blanket of snow ice in retarding the rapidly melting snow and ice, and increasing the ground absorption to 60 or 70 percent. of the melted snow and rain, and clinching the argument for reforestation and its effects." I thought during the week that the rise was hovering near the danger line, that a tremendous volume of water was getting away safely with no damage to property. If, however, 60 or 70 percent of the melted snow went into ground storage, we had only 30 to 40 percent of the water actually passing in our rivers. I can readily believe that so large a percentage of the water might have been held back on parts of the valley of French, Sandy, and Conewango Creeks, in the glacial sands, but for the majority of the tributaries the soil conditions are like most parts of the Monongahela basin, of little storage capacity.

Western Pennsylvania is well shown in Beins relief map to be largely hillside, ravines, etc. The rock is generally near the surface in nearly horizontal strata. Large springs are exceptional, while the slopes of brooks favor rapid discharge.

The following figures represent the mean precipitation on the Ohio water shed above Pittsburgh and its discharge at this city during the first three months of five years, 1903-7; both in billions of cubic feet. (Condensed from a diagram covering the months from January, 1889 to June, 1908).

JANUARY		FEBRUARY		MARCH	
Precip.	Discharge	Precip.	Discharge	Precip.	Discharge
177	162	112	108	218	242*

*March, more frequently than other months includes in its discharge snow water precipitated in preceding months.

It appears that for these three months the discharge of the river is about equal to the precipitation. It is thus clearly shown by the figures that there is little or no room for ground storage during such season for no more convincing evidence of the saturated condition of the ground can be presented.

Very different is the statement which can be made for the autumn months of the same five years for which the figures be low represent the means in billions of cubic feet.

AUGUST		SEPTEMBER		OCTOBER	
Precip.	Discharge	Precip.	Discharge	Precip.	Discharge
180	57	126	41	139	61

Regarding the diagram from which the figures are derived, I can say it was carefully developed from daily river and weather reports. For the several years the percent of discharge to annual rainfall, was compared with U. S. Geological Survey calculations for the Ohio at Wheeling. They compared fairly well. Compilations of volume of rainfall over extensive areas would be more reliable if the reporting stations were more numerous than they are in Western Pennsylvania and adjoining states still there is reason to believe the results given are within 10 to 12 percent of the reality. The figures thus made known for the first time for this vicinity, corroborate the belief which has been otherwise expressed by several writers, that especially for the great spring floods neither forests or other covering of the land has any appreciable influence in diminishing their height or volume.

PRESENT DAY NEEDS IN STRUCTURAL MATERIALS

A DISCUSSION

Chairman V. R. Covell: As stated in the announcement, the topical discussion, "Present Day Needs in Structural Materials" was intended to outline the work of the section for the year. The four subtopics deal with live questions which we hope to consider more fully at subsequent meetings. It is not the intention, at this time, to attempt solution of the problems involved but simply to present the needs in these various lines of structural materials so that the questions raised may serve as guides for development in future meetings.

Throughout his professional career, the engineer is constantly dealing with structural materials, and his standing as an engineer depends upon his knowledge of such materials and his ability to handle them sucessfully. With all the improvements of recent years no thoughtful engineer believes that final results have been reached. Many things are still to be desired in structural materials.

ROAD MATERIALS

BY S. D. FOSTER*

Roadways and the building of roads are problems that have worried and puzzled man-kind since the first dawn of intelligence in the human brain, and as his intelligence advanced, so has his ideas and methods of going and coming. Likewise, the routes and ways over which he must travel have in a measure been kept at a point almost equal to his advancement. The building of roads is, and always has been, the most important function of governments. All expansion is in a measure de-

*County Road Engineer, Allegheny County, Pennsylvania.

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pendent upon the roadways, dependent upon the ease of getting from one place to another. We might even say that roadways do not follow civilization, but that civilization follows the roadway. The pioneer goes into a new country and his only connection lies in the trail he has left. The civilization of that new country only advances as the trail becomes wider, more improved and more thickly settled. Two parts of a great country were connected by but a few old fashioned and very poor roads and there was no co-mingling of the people. They grew almost foreign to one another and when a great war was declared between these widely separated portions, the people of each stood ready to believe the worst of those who had once been their neighbors and countrymen. A closer, intermingling, of these people might have broadened their view and saved a Civil War. Today, I might cite Cuba, where the means of travel are so antiquated that the natives are really not acquainted with their compatriots of the next province, and it becomes the easiest thing in the world to instill a rebellion against the rulers.

The first great reason in many instances for building roads is for the transporting of armies and the carrying on of warfare. This has been the more forcibly brought to our notice here in the Western country, where we have for example the "Forbes Road." But, war is of short duration and peace always follows an invasion, and with peace comes the pioneer, followed closely by the pack-peddler, who, in time, settles and becomes a trader. Where business is started, there soon springs up a permanent settlement with schools, churches and social growth, and a civilization follows equal to the ease with which man can go back and forward and visit his neighbors. These few points show us the importance of roads, for we might say that almost our entire civilization and progress is dependent upon them. This we can better believe when we realize that people at all times and all nations have expended more labor and money upon roadways than upon any other public improvement. They may be called the community's greatest asset.

I have seen the natives of the South American jungle cutting their crude trails through the dense brush of a tropical country. I have followed the trail of the Spaniard from Cruses

on the Chagres River to old Panama, a trail built hundreds of years ago, and was fortunate enough to help in the building over part of that same trail an up-to-date macadam road of modern construction. In that country was, as I mentioned, the trail of the Indian, of importance to him only as a means of travel by foot or by horse to the nearest village or stream. The Spanish trail for use of old time pack-trains, when man's worldly goods and the products of his labor were transported from place to place upon the backs of mules; and the last and best, the macadam road of the present time built for the transportation of merchandise by trucks and heavy drays. In all of these roadways the one thing that impressed me was the evident desire of the builder, no matter how low the state of civilization, to put down a road that would, to use the slang phrase, "stay put," something that would resist the wear and tear of their time and environments.

This brings us to the present time and the present question confronting road-builders, of putting down a road that will "stay put." We have the fact that progress in means of travel has gotten one step ahead of our progress in the construction of roadway. The metalled top of the water-bound macadam road is no longer adequate to the traffic it is called upon to carry. The expense of maintenance of water-bound macadam roads has doubled, and in some cases trebled, within the past few years. This sudden rise in the cost of maintenance is due to several causes, but more especially to the great increase in automobile travel in all countries. The Massachusetts State Highway Commission has gone into this matter systematically and thoroughly and have figures to show that about 53 percent of the destruction is due to the automobile. From other sources of investigation, both private and government, we have the same reports, and it is a fact acknowledged by most highway engineers that the water-bound road of the past few years will soon make way for something more durable. The automobile is here to stay, and it will not be long until the farmer will have his produce brought to market by motor and the merchant will use a truck for delivery of goods throughout the country.

The need of a new wearing surface to care for this ad-

vancement in travel is the one great question which the highway engineers must face. The damage done by the automobile to water-bound macadam roads comes from three causes. The first, that by reason of the power exerted on the axle of the driving wheels, and the machine running at high speed has, by government test, shown a marked slip upon the surface of the hard roadbed, such as is often seen in an exaggerated manner on a frozen surface. The second is the suction of the rubber tires, which have a tendency to draw out from between the stone the fine binding material; and the third, the low hanging machinery of most cars restricts the space from the top of the road to a narrow opening, which the rapidly moving car transforms into a draft. The suction picks up all loose particles of stone and dust, making the immense clouds which we see behind a rapidly driven machine. This material is blown away into the fields and just so much of the road is gone.

Likewise, we will always have the vehicle drawn by the horse and have to take into consideration that the horse pulls his burden and must have a foothold on the roadway in order to draw his load, thus bringing into the problem another, probably the greatest after the automobile, of the destroying agencies upon the wearing surface, for the caulks upon the horses shoes, where he must exert great power in drawing his burden, tear out small parts of the roadway, and the following wheels grind this into powder which the elements soon carry away.

This trouble, of course, is remedied to a degree in our cities by what we term "pavement", which includes sheet asphalt. brick and the several different kinds of block which give a smooth, hard surface, capable of withstanding the wear of the heaviest trucks and on which the automobile shows no detrimental effect. Now, comes the question as to whether we shall carry out this idea of pavement on our country roads, or find a binder having the requisite qualities to withstand the injurious agencies mentioned before. We cannot obtain a perfect road which in theory should be durable, dustless and mudless. It must possess resilience, be sanitary, noiseless and not slippery, and above all, be cheap both in first cost and maintenance.

Such a road would of course be the ideal, the perfect road, but it is also the impossible, in that it would mean the admission of qualities that are absolutely opposed to each other and cannot be united in one road to the full advantage. For example, if we would have a roadway noiseless, and resilient for horse traffic, it must needs be more or less soft and so not likely to give the wear that the harder surface would. Thus, it will be seen, that sacrifice of perfection must be made to give the practical road which will suit the prospective traffic which it must sooner or later be called upon to bear.

As this is to be but the preliminary paper to open a general discussion on the present day needs of road material, I would suggest that the discussion be carried on under the two heads, "The Need of a New Wearing Surface," and "A New Binder for our Present Roadways," understanding, of course, that this binder may be either of two kinds, the asphalt or tar compounds and the portland cement, one giving an elastic bonded surface, the other a firm and rigid roadway.

REFRACTORY MATERIALS

BY KENNETH SEAVER*

In considering the problems confronting the engineer in the selection of high refractories, as well as the solutions attempted, with whatever measure of success, by the manufacturer, it is manifest that but the briefest discussion can be given in the few moments at our disposal, yet I cannot refrain from somewhat emphasizing the importance of this class of material, inasmuch as we might say where it is at all important, it is all-important. For instance, the blast furnace, the hot blast stove, and the open hearth, are in reality but structures of fire brick or other refractory suitably enclosed.

The modern blast furnace, with its complicated and involved engineering problems, has arrived at its present comparatively highly efficient state only as its advances have been kept pace with by a proper development of the refractories used in it and its component parts. It is a far cry from the old square stone blast furnace of the earliest type to the modern steel clad

*Engineer with the Harbison-Walker Refractories Company.

monster pouring forth its enormous tonnage, and its problems while solved for the day, may in its development call for an entirely different solution on the morrow.

Naturally, the problems relating to high refractories are incapable of an exact and mathematical answer, and the problem of the blast furnace, for instance, the old type furnace using cold blast, required another solution with the advent of the hot blast stove, and as this was in turn succeeded by the still more modern types with greatly increased temperatures and vastly larger volumes of wind, still further development was necessary in the matter of its lining. Within the last few years the constantly growing use of the Mesaba ores and of the difficultly reducible magnetites, as well as the very refractory Cuban ores, and the increased percentage of flue dust in the furnace burden, each brings its new problem not only to the blast furnace engineer, but to the producers of refractory material.

In general, it may be stated that the problem involves three factors, or some combination of these factors, the inclusion of extreme heat as one being, of course, axiomatical, while besides this, there is the factor of chemical action, as well as mechanical or physical abrasion. In any given problem there may be but one, two or all three of these factors.

It will be possibly the best method to consider some of these problems in detail, as they apply to different industrial operations in various types of furnaces; for instance, in the blast furnace, the first factor, heat here varies from that of the top, which we may assume at from 400° to 600° Fahrenheit, to that opposite tuyeres, where it reaches approximately 3500°. The chemical factor is, in this particular type of furnace, one about which comparatively little is known, and there is ample opportunity here for further investigation and experiment. It is known that, due to the action of the nitrogen of the atmosphere upon the incandescent coke, there is considerable cyanogen formed which has a decided affinity for any sodium and potassium present, forming cyanides which, in turn, are, as they pass upward in the furnace, decomposed into carbonates, and it is possible that these alkaline carbonates act with the brick to form a comparatively easily fusible silicate. However,

there is very little real information on this subject. It is true, at all events, that this theory may account for the fluxing of linings at a considerably higher point in the furnace than should be normally the case.

The abrasion is, of course, most severe at the top where the stock impinges against the walls as the bell is lowered, and is severe throughout the entire furnace shaft until very near the zone of fusion.

The use of zinky ores, for instance, such as are peculiar to the Virginia fields, also introduces another problem. Even the highest grade of material being comparatively permeable, there is deposited in it large quantities of metallic zinc from the zinky vapors. This deposit causes the brick to so swell that enormous distortion of the furnace results, in some cases the entire stack being thrown out of line several feet. There is here the problem of manufacturing a brick which shall have requisite refractoriness, resistance to abrasion, and at the same time be so unaffected by this deposition as to give a satisfactory life. Still other questions are brought up by the introduction of the newest type of blast furnace with the so-called "thin" lining, the entire shell being water-cooled and the lining being only 12 in. in thickness, with the exception of the bosh. Here only the highest grade of refractory, and that satisfactorily prepared, has any chance of giving proper results. This furnace lining, as you are doubtless aware, is being given very thorough trial in at least two plants in this country, although it has been, we understand, for a number of years in operation abroad.

In the hot blast stove, not only must the brick withstand the high temperatures and repeated stresses caused by the changes in such temperature, but the markedly disintegrating action of the gases. It must also have proper physical strength to bear the weight of the superimposed mass of brickwork of 100 feet or more. The failure to solve this latter problem has, in one instance, resulted in the necessity of shoveling out the stove complete within a year from being put in blast, whereas the successful solution may mean from 14 to 15 years run.

Each year sees a constant increase in by-product coke oven construction, and it is undoubtedly becoming one of the factors in the conservation of our coal resources. Its development is bringing up new problems. The refractories originally deemed entirely satisfactory have since been discarded by all advanced designers, and new refractories capable of withstanding higher heats and with much greater conductivity are employed. The question of minimum expansion or contraction is here an all-important one, as well as the ability to withstand abrasion. The beehive oven, comparatively simple as its questions may seem, has seen and is seeing great progress as well. As a rule, the materials once employed are by no means satisfactory when viewed from the modern economic operating standpoint. This is particularly true with the use of the high volatile coals such such as occur in the Klondike and other regions. The coke oven industry, as a whole, is one of the latest to realize fully just how important are the solutions of its problems.

Connected with this problem of beehive refractories is that of waste heat flue construction. Experiments have been conducted along these lines for a number of years, and with one of the largest coke oven operations in this country had come to such a pass that, regardless of the large saving, the feasibility of the whole scheme depended on the finding of a suitable fire brick or silica brick which should withstand the intense heats encountered in the underground flues and at the same time avoid any difficulty from spawling. This question has apparently been satisfactorily solved, and marked economics can be looked for in its adoption.

In the rotary cement kiln, the lining of which has to withstand not only the high heats and the abrasion of its charge, but the chemical action of the highly heated basic cement clinker, there are introduced secondary problems by no means unimportant in every change of mix. It is, of course, the aim that the lining should have such mechanical and chemical characteristics as shall enable it to pick up and hold a coating of clinker. Otherwise, the fire brick itself would be rapidly destroyed.

In the ever recurring problem of maximum production at

minimum cost, the aim has been to secure in retort gas house practice, material which shall give much longer life than the old clay retorts, shall withstand higher heats and shall have increased conductivity, so that the gasifying of the coal may be done in a shorter time and at decreased fuel consumption. The results of recent tests show this problem is in at least a very fair way of solution.

Although in general the type of refractories used in open hearth work has seen little change, there is constantly the search for fire clay, silica, magnesia and chrome brick which shall give even a longer life, and the relative importance of refractories in this phase of the steel industry can be readily appreciated

The development of the electric furnace is the occasion of much research for refractories peculiarly adapted to its needs, and although the silica and magnesia brick in use in the open hearth are now employed, there is a search for other materials, should they be available.

The question of a satisfactory retort for the distillation of zinc is as yet by no means solved. So near the temperature of fusion of the retort is it necessary to carry the heats in order to secure the volatilization of the zinc that there is but the narrowest factor of safety, and thus far, the effect of the various oxides is such as to preclude the use of certain refractories which otherwise might give good results. Much experimentation is going on, with the idea of lining clay retorts with chrome, but it is as yet too early to predict the final outcome.

Enormous developments bid fair soon to occur in certain types of calcining kilns, these kilns making available deposits of iron ore which were formerly, due to the high sulphur content, not economical to roast. In the particular type of kiln in mind, there is the introduction of a muffle by which the sulphur gases are kept separate from those of the combustion gases and are employed in the manufacture of sulphuric acid. Here the great conductivity of magnesite is the essential. This is one of the most interesting recent developments.

In addition to the three factors which in general we have already considered, there is yet a fourth which we may term the

personal equation and which is yet a most vital factor, i. e. the treatment which the refractory receives at the hands of the user. In the same type of furnace a given refractory may give excellent results while operated by one, but be a complete failure in the hands of another. Knowledge and care in the operation of the furnace is all-important.

It will, of course, occur to you that the above brief summary is nothing more than a catalogue of a number of such industrial plants as are users of refractories, but this brings out exactly the point which I would emphasize, i. e. that practically all these problems are in a measure solved, but not necessarily permanently solved, and that there is a constant reaching out for a better solution for each one.

There is yet another problem which we have not mentioned, and that is, the problem of the education of the user of refractories to an appreciation of what quality means and to a realization that cost must be figured on tonnage output and not on the original price per thousand. In numberless instances the solution of refractory problems is but a question of bringing the consumer to realize that there is at hand a remedy for his troubles, if he will but avail himself of it.

That the progressive manufacturer is seeking to the best of his ability, a solution of these problems, is evidenced by the increasing amounts expended for research along all lines which may seem to bear upon it, and the discussion of these problems in the literature of today is undoubtedly having a great and beneficial effect. Undoubtedly one reason for the comparatively slow adoption, by the consumer, of certain grades of fire brick and silica brick, has been due to the lack of information of the manufacturer as to the exact conditions to be fulfilled. This has been due, in a measure, possibly, to a lack of initiative on the part of the latter and also to a mistaken policy of secrecy on the part of the former, but this day is passing, and there is coming to be, between the producer and user, a full realization that only by the heartiest co-operation and exchange of ideas can there be an efficient and satisfactory solution of the problems involved.

FIRE PROOFING PROBLEMS

BY C. B. ASHER*

My understanding of the treatment of the subject assigned to me is that it is to consist only of a recounting, or statement of some of the problems met with in hollow tile fireproofing work and is not to be an attempt at solutions of these problems.

I shall therefore endeavor to present a brief synopsis of the various considerations and problems encountered in the use and adaptation of hollow tile fireproofing material, leaving the discussion of the problems of manufacturing to others.

The strength of a building depends upon the strength of its structural parts, the columns, girders and beams. For years men have been seeking some structural material which would retain its shape and strength after being subjected to fire, some material which would be fireproof.

Fifty years ago most people firmly believed that cast iron was absolutely fireproof, and thousands of buildings were erected using this material. After a few fires this belief was quickly proven to be a fallacy.

Attention was then turned to the unprotected steel frame building, which was soon found to be subject to absolute destruction by a severe fire. Notwithstanding this fact a great many people today believe steel to be a fireproof material.

The next step in the progress of fireproof building construction consisted of covering the structural steel members with burnt clay, and the excellent results which have been secured with this material, as testified to in the numerous severe tests which it has undergone, fully justify the faith which is placed in hollow tile as a fireproofing material.

The quality of the material used is one of the most important factors. The tile should be of what is commonly known as semi-porous material. This material is sufficiently porous to afford excellent fire protection and still give the strength which is demanded.

The hollow tile fireproofing work in one of our modern steel skeleton buildings usually consists of floor arches, beam and girder covering, column covering, and partitions.

*Engineer with the National Fireproofing Company.

A few of the questions arising in regard to the design of the fireproofing for such a building are:

(1) TYPE OF FLOOR ARCHES.
- (a) End construction.
- (b) Side construction.
- (c) End construction with side construction skews.
- (d) Segmental arch.

(2) PROTECTION FOR BOTTOM FLANGE OF FLOOR BEAMS.
- (a) Thickness of tile.
- (b) Shall the tile be made solid, or shall an air space be left at the middle of the flange between the tile and steel?

(3) GIRDER COVERING.
- (a) Thickness.
- (b) Method of fastening, especially to plate girders.
- (c) Shall entire girder be fireproofed before arches are set or shall arches be set and then the portion of girder extending below bottom of arch be fireproofed?

(4) COLUMN COVERING.
- (a) Thickness of tile.
- (b) Distance from face of steel work.
- (c) Methods of fastening.
- (d) Shall one or two thicknesses of tile be used?

(5) PARTITIONS.
- (a) Thickness.
- (b) Provisions for pipes and conduits.
- (c) Provision for fastening work of other trades.

Aside from the problems just mentioned as arising in connection with steel skeleton fireproof buildings there is another field for fireproofing work which has just opened up within the last few years, namely, the construction of fireproof houses.

This is a subject in which every one is vitally interested and the tremendous fire losses sustained every year by reason of flimsy wooden construction, together with the large increase in price of lumber and the growing scarcity of good lumber rend-

ers it imperative that some form of construction be devised to replace common present day methods.

Within the last five years over 3000 residences, stables, garages, etc. have been built in the United States using hollow tile fireproof material for exterior and interior wall construction and for floor construction.

Not all of these buildings have been made fireproof throughout, some of them having the hollow tile for the wall construction only and using the ordinary wooden joist floor construction.

For the wall construction special heavy tile with dove tailed scorings, are used and these tile are then plastered on the exterior with two coats of portland cement mortar. The dove tailed scoring provides a mechanical bond for the cement plastering, which is a guarantee against any cracking or scaling off.

For the floor construction the hollow tile are used in connection with a reinforced concrete joist placed within each row of tile.

The wonderful demand for this construction in the short time it has been used augurs well for its future.

At present a fireproof house costs from 5 to 20 percent more than a house with wood floors and partitions. The development of the modern fireproof house and especially the cheapening of the small house offers more attractive problems than any other phase of fireproofing work today, and I firmly believe that within the next decade, an absolutely fireproof house can be built for the same amount of money that would be expended on an ordinary structure.

TIMBER

BY E. F. WENDT*

The railroad timber problem is one that would require a very extended discussion were it treated with completeness. In the short time of ten minutes I can merely mention a few of the particular problems to be met in every day maintenance and operation of railroads.

Timber is used in four of the departments of the railroad.

*Assistant Engineer, Pittsburgh & Lake Erie Railroad Company.

the car, building, bridge, and track departments. In so far as cars are concerned that does not come within the experience of the speaker. However observation tells us that the timber problem in the car department is being solved by the substitution of steel.

In the building department of a railroad timber is very necessary. Formerly there was no difficulty in obtaining a liberal supply of pine but at present it is exceedingly difficult to obtain and keep supplies of this kind, hence the problem is being met in all progressive railroads by the substitution of brick or other materials. Brick structures are now most common, even in the smaller structures. On our own road, the P. & L. E. R. R., buildings of every description, outside of the little buildings used for crossing watchmen or at other points where there is likely to be a change, are being constructed of brick. However many movable buildings must be constructed of timber and the problem is to get a supply of satisfactory lumber. The use of the lower grades, what were formerly the cheaper grades, is now quite common. These cheaper grades were considered unworthy of use 25 years ago, but we are now forced to use them and we are preparing to use them with economy to the very great good of the railroad itself from the standpoint of cost.

When we come to the bridge department and have to do with structures which carry the cars and locomotives, the problem is not so easy. While we can construct steel and concrete and reinforced concrete and stone structures, yet it is at times necessary to provide a great deal of timber trestling and other structures for the support of the tracks. In that work piles are necessary and large quantities of 12 in. by 12 in. timber and stringers of the ordinary size 8 in. by 16 in. by 30 ft. Ten years ago we could get white pine stringers without difficulty; now it is a most serious problem. Yellow pine and Oregon pine are about the only ones that can now be secured, and the price has gone up. In our practice we use very little timber in what is called trestling for the reason that the subject of maintenance of the structure and even of its safety has come up within six years and we are confronted with the question of either reconstructing these structures or substituting other material. Economy may

enter into the question to the extent that we may say positively that it is cheaper in the long run to construct permanent structures if we are at all certain their life will extend over 10 or 15 years. Where we cannot do that of course timber will continue to be used and the great problem before the bridge department, after getting the timber is the matter of preservation of the timber that is actually used in these structures. How can it be done and at what cost and will it be economical to do so or will it be more economical to substitute some other material?

But the great user of timber in the railroad organization is the track department and its problem, the procurement of 150 000 000 cross ties every year, to keep the railroads of the country in a safe condition, is no simple one. It is one of the most serious problems which confronts the purchasing agent, and necessarily through him the management as a whole. Just what its ultimate solution will be we cannot say with certainty. If any person can design a satisfactory substitute for the timber cross tie he can retire from business at once for his fortune will be made. A very large number of people have attempted to design substitutes and a very large number of cranks call at our offices to interest us in their wild ideas, but a satisfactory substitute is yet to be found. Many substitutes have been attempted and some are being used with considerable success. But timber makes the best railway sleeper and as long as it can be procured at a reasonable cost, say $1.00 for a good 7 in. by 9 in. by 8 ft. 6 in. white oak tie, it probably will be used in preference to any other form we know of at this time.

The problem incident to the purchase of this large number of cross ties is equally difficult. We find in the same region, for instance Kentucky or West Virginia, where we are now obtaining very large numbers of cross ties, that each railroad maintains a corp of inspectors. I have in mind a point where the Pennsylvania Railroad keeps about ten inspectors all the time, the Baltimore and Ohio Railroad an equal number, and a large number by the Lake Shore Railroad. One company is simply bidding against another as to who will get the timber in that region, and bidding against each other by lowering the standard in order to get a sufficient quantity to keep the road in repair.

That shows how anxious the companies are to get the necessary amount of timber to keep the roads safe, because there is no substitute that can readily be used.

The great problem after we obtain the timber is to so treat it that it will not decay and become useless in a very short time. I do not now refer to chemical treatment, but how to use the timber in a manner to bring the greatest results without chemical treatment. You know the first thing a railroad does is to use that old time barbarous track spike, and decay starts at once. A spike never stays in the position in which it is driven, it is immediately drawn up and the track man comes along and drives it down and it comes up again within the next thirty days, so that the moment a tie goes in the track decay begins. Furthermore railroad trackmen are very extravagant in the use of timber and education is necessary to prevent the great waste that has been going on in the past. This is a practical problem, the prevention of waste, and it would pay the railroads to exercise more careful supervision. In our experience during the past seven years the average age of white oak cross ties in track is 12½ years, or a renewal of 8 percent annually. But in many parts of the country white oak cannot be obtained at all and the average life of other oak is five years instead of 12½ years.

Now what satisfactory substitute can be found for the timber tie? I am not prepared to say that a substitute will not be found. We have 3000 steel ties in one of our main tracks at McKees Rocks which have been in 30 months, and which are fully equipped with electric circuits, with no signal troubles in the 30 months and no renewals, and the track has been maintained in good line and service at a reasonable cost. Those ties are just as good today as the day they were put down. But experiments on a small scale with slow speed tracks is not conclusive and we should not base a full conclusion on a short test. There are other substances being tried, such as reinforced concrete, which can be used in the more unimportant tracks, but in main tracks where the speed ranges from 60 to 80 miles an hour the use of the old 7 in. by 8 in. white oak cross tie will continue for many years to come.

The principal problem in the operation of a railroad from the standpoint of maintenance at this present day is to preserve the life of the timber by some kind of chemical treatment. There are many such processes in use now and they are all worthy of most careful study. We know that it is possible to extend the life of ties from 12½ to 18 years or longer, and if this is possible it should prove economical. And there is another incentive to such treatment because even if the supply of timber was reasonably good, within a very few years timber will become so expensive that unless chemically treated maintenance costs will go up by leaps and bounds. That there is still a large quantity of timber in this country is apparent to anybody who travels over it. Last year I made a special trip to Louisiana and Arkansas and found very large quantities of timber. There are large tracts in the South and in the Northwest, and if the timber were cut intelligently by the woodsman, avoiding the wasteful methods of cutting, we would have a supply of timber which would possibly carry the industries of the country along in a very satisfactory manner. Conservation is one of the most important problems the country is up against and the railroads are most vitally interested in it. How to cut timber in the woods is not a simple question. Reforestation is a practical problem. In the South we find that it takes 40 years to reproduce a white oak tree large enough for railroad cross ties. For instance we saw fields which in the Civil War were cotton fields and today nothing is seen but splendid forests of oak trees now large enough to furnish cross ties.

But suppose the country does reach a point where extravagance is discontinued, and suppose we do become intelligent in the use of timber. Economy as well as intelligence demands that timber should be treated chemically. Very little treated timber is used on railroads in the eastern part of the country as yet. Treated cross ties for track use are almost unknown in the east. But the Pittsburgh & Lake Erie Railroad made a start in the treatment of some bridge ties that are to be placed on the new bridge over the Ohio River at Beaver. What results we shall obtain will not be known for some years, at least

five and possibly eight. We hope that the antiseptic which has been applied will result in a much prolonged life.

I have spoken of some of the things that merely occur on the surface. The real problem as I see it, outside of the difficulty of getting timber for the maintenance of the railroad, is bound up in the word conservation, and as engineers we should support the men who have made a beginning in bringing this question, from the standpoint of the government, to the attention of the American people. These men in the Forestry Department have certainly done well in putting the work on an intelligent basis. As engineers and as railroad men engaged in the construction and maintenance of railroads we ought to advocate the chemical treatment of timber to give it, not a life of ten years, but of 20 or 30 years so that the supply of timber which is coming on in this country, if intelligently cut and intelligently used, will serve the needs of the people. I firmly believe in education, and if intelligence is applied to this problem by the engineer, extravagance will disappear and ultimate economy will result.

There are other practical problems which come up in daily life in connection with the operation and maintenance of railroads regarding the use of timber, but I think they can all be bound up in the policy of conservation, the intelligent use of that which is at our command and the support of a policy will preserve the timber of the country rather than permit it to be ruthlessly destroyed. My observation of the forests leads me to believe that proper attention has not been given to the cutting and use of timber and the time has now arrived when the country must in some measure arrest the great extravagance which has characterized the American people in their treatment of the forests. We have been extravagant just because the country has been rich. We must however be economical in the future because we have been extravagant in the past. And if we are economical I am disposed to believe that our country has in it, and the neighboring countries have in them, a supply of timber, not of the grades we have been using in the past, but of inferior grades which can be adapted to the uses which must be met by timber in the future.

STEEL

BY R. B. WOODWORTH*

To give an exact definition of steel under present conditions is rather a difficult matter and limitless variations may be found in writings on materials of construction. A writer on the preservation treatment of steel, for example, defines it as iron plus carbon plus impurities plus metallurgists, indicating thereby that large differences in steel are due to differences in the methods of manufacture and in the men who control them, and doubtless there is a great deal to be said on that subject, though it may also be said that the quality of the steel is in a measure fixed by standard specifications and the variation in the output ranges within definite limits.

Previous to about 1860 there were three important classes of iron: wrought iron whose essential characteristic was its nearly complete freedom from carbon; steel, an iron with a moderate carbon content sufficient to confer the property of intense hardness when suddenly cooled from a high temperature without, however, causing brittleness on gradual cooling; and cast iron, characterized by a carbon content so high as to make the metal brittle under all conditions of cooling. This classification was based on carbon content or on the properties which the carbon gave. Between 1860 and 1870 a new class of iron was introduced known today as mild or low-carbon steel without the property of hardness when suddenly cooled yet different from wrought iron in its freedom from slag and from cast iron in being very malleable. The word steel today stands rather for excellence than for any specific quality. It may be made by the bessemer, open hearth or crucible processes, may be associated in alloy with nickel, chrome, tungsten, molybdenum, titanium, vanadium, etc., etc., or with combinations of two or more of these, may perform any service of which wrought iron is capable and yet preserve its identity as a material of construction essentially different from a wrought iron of identical chemical constituents. Nearly all wrought iron is made by the puddling process and contains very little carbon, but does contain slag which is rolled out into long threads that break the con-

*Engineer with Carnegie Steel Company.

tinuity of its texture and constitute lines of weakness: steel, whether bessemer, open hearth or crucible, is freed from slag by fusion, is malleable like wrought iron at least in some one range of temperature, is either cast into an initially malleable state, or is capable of hardening by sudden cooling, or is both so cast and so capable, and is practically homogeneous throughout. Cast iron cannot be rolled or forged, it is neither malleable or ductile.

Wrought iron contains 0.30 percent carbon or less, rolled steel contains various amounts in accordance with the hardness or tensile strength required. Dead soft open hearth steel used instead of wrought iron for welding purposes, for example, contains 0.08 to 0.12 percent carbon; soft steel in rivet rounds 0.12 to 0.18; while the steel used in the manufacture of rolled wheels runs from 0.65 to 0.85 and that made into railway springs from about 0.90 to 1.10; some tool steels go even higher.

Steel contains like wrought iron a small percentage of phosphorus and sulphur which ordinarily are its most objectionable ingredients and which except for special purposes, it is the endeavor of all manufacturers to keep below certain limits. An additional constituent is manganese which is introduced to deoxidize the steel and to counteract the injurious effects of sulphur and which in addition thereto increases somewhat the hardness and the elasticity of the material. Whether or not this introduction increases its liability to corrosion is a matter much disputed. The main argument on which the contention that it does is based is the electrolytic one, that increase of elements in the mixture carries with it larger possibilities of differences in electric potential, a theoretical consideration the practical validity of which still lacks final demonstration. If it does so, it does it by reason of unequal distribution of the manganese rather than by inherent action.

Present-day needs in steel, considered as a structural material, may be classified, for the purposes of this paper, into four divisions:

1. The Manufacture of Steel.
2. The Design of Structural Steel Members.

3. The Fabrication of Structural Steel Members.
4. The Maintenance of Steel Structures.

THE MANUFACTURE OF STEEL: The introduction of steel as a material of construction in a large commercial way was due to the invention of the bessemer converter followed in turn by the invention of the open hearth furnace, and it is due to improvements in these appliances that steel has become the important material of construction. Recent years have witnessed the introduction of the electric furnace and the application therein of electricity to the manufacture of steel. The electricity serves simply as a source of heat and does not exert any peculiar action of its own. On account of the present high cost, it is only available for special grades of steel and in competition with the crucible process. It may be well to note some of the modern kinds of steel and their uses:

Armor plate is made under patented processes. It frequently contains nickel and chromium to give increased toughness and strength but with so little carbon that it cannot be hardened. The impact face of the plate is given the intense hardness needed by conversion into high carbon steel at a high temperature with exposure to a bed of charcoal, illuminating gas or other source of carbon. The impact face thus carburized by absorption is suddenly cooled with the result that there is produced a plate with an intensely glass hard impact face, integrally united with an unhardened, ductile and slightly yielding interior and back. Such plates have come into extended use for shipbuilding, vault construction, etc., where weight, hardness and toughness are essential.

Chrome steel, that is to say, steel containing in addition to its other ingredients a percentage of chromium, combines, when "hardened," intense hardness with a high elastic limit so that it does not suffer permanent deformation or fission from extremely violent shocks. It is, therefore, used for armor-piercing projectiles, certain rock crushing machinery, for bank and office safes, etc.

Manganese steel contains about 12 per cent manganese and 1.50 carbon and is characterized by great hardness with extreme

ductility when cooled suddenly. Its behavior in the latter respect is just the opposite of that of carbon steel. It is used, therefore, for objects which require both hardness and ductility, such as rock-crushing machinery, railway frogs and crossings, rails, mine car wheels and safes. Its hardness makes machine work thereon difficult and expensive; its elastic limit is also relatively low.

The merit of tungsten steel is that, like manganese steel, it retains its hardness even after it has been heated to high temperatures. It is used for magnets because of its great retentivity, and or lathe and similar high speed cutting tools which are to take off a thick slice at each cut. Chromium may also be added to the tungsten in high speed tool steel to produce greater hardness.

Titanium has been used experimentally to a limited extent in the manufacture of cast iron car wheels and other castings, and in the manufacture of steel rails; its uses has also been recommended in connection with rolled steel wheels. It acts as a deoxidizing and scavenging agent in the removal of impurities and is said also to combine with and remove any nitrogen present.

The addition of vanadium to steel serves to remove the last traces of oxygen and probably of nitrogen, to harden the material and to reduce its tendency to break under repeated stresses. It has a very great effect in raising the elastic limit and to a less degree the ultimate tensile strength. In cases cited the elastic limit has attained to 93 percent of the ultimate tensile strength. Vanadium steel is extensively used for automobile parts and other machinery liable to sudden shock and may be looked upon as an established material of construction for severe service under alternating stresses. It is also used in the manufacture of razors and other fine cutlery and has the advantage of retaining its edge much longer than other steels. It may come into consideration for structural purposes in the manufacture of pins, rollers and the mechanism of swing bridges. Chromium is sometimes added, and then the product is known as chrome-vanadium steel.

Nickel steel combines very great strength and hardness and

a very high limit of elasticity with great ductility. Its large use in shipbuilding, together with other causes, has called the attention of structural users to its use with other structural materials for bridge building. With the addition of 3 to 3½ per-cent nickel the elastic limit and the ultimate strength may be largely increased without, however, giving rise to the disadvantage of great hardness which accompanies the endeavors to reach a high tensile strength and elastic limit by the use of carbon alone, the effect of the nickel being to toughen the material and to increase its relative ductility so as to permit more enomical working under structural shop equipment. Much is to be expected from the use of nickel steel for the tension members of large bridges. It is a question whether it is any better adapted for members in compression than the usual medium or high carbon steels. The combination of ductility with a very high limit of elasticity makes it, however, very valuable for shafting.

Some chemists trace to manganese the high corrodibility of ordinary structural steel as compared with cast iron for example, and there has recently been put on the market a material known as ingot iron which is rolled into sheets, plates, etc. This material is covered by letters patent which call for a pureness of iron of at least 99.8 per cent. Analyses made for the manufacturer show but traces of manganese and silicon and very low percentages of sulphur, carbon and phosphorus. Advertisements state that in it corrosion has met its Waterloo.

The need in the manufacture of steel today is for an exact demarcation of the limits of use of these various steels and more exact knowledge as to the conditions favorable or otherwise to which their employment gives rise. Alloy steels have their advocates and they are being pressed as panaceas for all known ills in steel manufacture or uses. Time will give each material its proper position in which will be found its most economical and satisfactory use. Investigations as to their relative merits are in progress in different parts of the United States, principally in connection with the subject of the maintenance of steel structures and much is to be expected in the way of knowledge

from the full discussions to which the reports of these investigations will give rise.

THE DESIGN OF STRUCTURAL STEEL MEMBERS: The engineers of this Society are principally engaged in the use of soft or medium structural steel which will analyze about 0.20 carbon, 0.45 manganese, 0.015 phosphorus and 0.04 sulphur with a tensile strength of 60 000 lb. per sq. in., and the next questions have to do with the use of this material in the design of steel structures and the physical properties which conform to the chemical analysis.

The ultimate tensile strength of steel and its elastic limit in tension is a matter of very easy determination and is ascertained by the pulling apart of test pieces on an ordinary testing machine, and the only practical difference among engineers is just what proportion of the ultimate tensile strength should be considered as the actual working stress.

In fact the relation between the chemical ingredients of a steel and its ultimate tensile strength under certain conditions of manufacture are of sufficient uniformity as to permit the calculation of the tensile strength from a chemical analysis with an approximate correctness dependent upon the correctness of that analysis. Heat treatment and work may modify the formula, but for structural steel made by the basic open hearth process and rolled under good rolling conditions very close results are given by H. H. Campbell's formula:

$$S = 38\,800 + 65\,000\,C + 100\,000\,P + 9000\,M + 40\,000\,CM$$

in which

S = Ultimate tensile strength per sq. in. 38 800 = Ultimate tensile strength of pure iron.

C = percent of carbon.

P = percent of phosphorus.

M = percent of manganese.

American practice is to use 16 000 pounds per square inch for building construction on a steel ranging from 55 000 to 65 000 lb. in ultimate tensile strength and we say that such steel has a factor of safety of four. Our European compeers are rather more consistent in using 15 000 lb. per sq. in. There are

structures designed on this side, however, in which the dead and live loads have been taken on stresses ranging up to 23 000 lb. per sq. in., and by doing so have been brought under the criticism of being too close to the ragged edge. The difficulty consists not in the tensile strength of the steel used but in the standpoint of the designer towards its use.

"The subject of compressibility in beams has not even in the present day been reduced to accurate mathematical treatment. Notwithstanding Saint Venants' classical memoirs on the flexure of prisms, the application of the general equations to special cases of the bending of beams under longitudinal pressure still presents difficulties which have not been generally surmounted." In fact the whole subject of the compressive strength of structural steel shapes and members needs careful investigations and the failure of the Quebec Bridge by reason of the overloading of compression members has brought most acutely to the attention of engineers the fact that a large problem today in the use of structural steel is the matter of its compressive strength and the allowable loads in compression on members, particularly of large size. A committee for the investigation of steel columns and struts has been appointed by the American Society of Civil Engineers. It organized on January 6th, 1909, and its preliminary report was published in the December Proceedings of that Society. This report indicated most of all the wide differences in results obtained by independent investigators and the committee in making its report very justly refrained from making any new formula based on the tabulation of previous results but advocated the investigation of the whole question by the United States Government with the use of testing machines of large capacity.

Compressive tests are not easy to make and the results obtained must be adjusted by various factors, one of which is the proportion of length to the radius of gyration. It is definitely understood that this is not the only factor of importance but that the shape of the member, its details and its dimensions may have a good deal to do with its performance in the testing machine or under conditions of loading. Of course for ordinary building construction the present straight line

formulas, such as published in the Carnegie Steel Company's Hand Book or as recognized by the New York Building Law, give eminently satisfactory results and there is no need to question the security and safety of the structures which have been erected under these formulas. With large size members under high unit stresses conditions may be entirely different. The Quebec Bridge failure also called attention prominently to the necessity of internal systems of bracing in large compression members and there is no question in the writer's judgment but that a part of the failure was due to the lack of a proper system of lattice and cross bracing. The question of lattice bars and lattice bar spacing is tied up with the question of compression and both of them need thorough investigations if departure is to be made from ordinary recognized standard practice.

The same thing may be said in regard to shearing stresses. It is well known that controversies are quite bitter in the use of reinforced concrete as to the proper location and need for inclined shear members. Relatively the same uncertainty exists in regard to the treatment of the shear in steel. It is commonly assumed, for example, that the shearing value of steel is 75 percent of its ultimate tensile strength and the formula for obtaining the buckling values of web plates in plate girders are based on the use of 12 000 lb. safe vertical shear as against buckling, which is supposed to give a factor of safety of four as against 48 000 lb. per sq. in., corresponding to an ultimate tensile strength of 64 000 lb. The allowed shear on a 15 in. rolled steel beam, which tested to a load of 95 680 lb. at the supports, ranges according to the various formulas given in the Hand Books and in specifications, from 45 660 lb. to 94 010 lb., and the formulas which show lower, and presumably more correct values are based on experiments made long years ago on wrought iron. A new formula for shearing values in webs and web plates is greatly to be desired if by its publication the confusion which now exists in hand books and specifications could be eliminated. The whole subject is one which demands thorough investigation under modern conditions of manufacture and use. It is not a matter of lack of safety in structures designed by the use of conservative formulas but with the modern

tendency to conserve materials wherever possible and to use the lightest members which will do the work, exact knowledge and precise formulas have become more indispensable.

THE FABRICATION OF STRUCTURAL STEEL MEMBERS: This division of our subject is one which does not need very much discussion in this connection, especially because of the fact that not long since Mr. S. E. Duff honored this Section with a thorough and competent discussion on it.[1] Methods in shop manufacture are improved upon daily. The fabrication of steel products under stress of competition calls forth the best endeavors of operators and shop managers and the greatest problem is not the problem of the materials used but of the men who use them. Labor, it is said, has become more aggressive and less efficient, and the success of a modern fabricating shop demands the same business sagacity in the sales department and the same efficient management in the shop as is needed in other lines of business. The problems, therefore, are rather administrative than engineering.

THE MAINTENANCE OF STEEL STRUCTURES: This problem is perhaps the most important of all that concerns the steel world today and is being given careful attention by a number of investigators. The subject of the corrosion of iron and steel goes hand in hand with the question of preservative treatment. The American Society for Testing Materials first appointed a committee on preservative coatings for structural materials. It soon discovered there was need for a committee to ascertain the facts as to the corrosion of iron and steel in order to reach sound conclusions as to the use of preservative coatings. The work of Committee "E" on preservative coatings is therefore co-ordinated with the work of Committee "U" on the corrosion of iron and steel, both in a measure overlapping each other and both being subsidiary in a way to each other. The subject has received the careful attention of the Bureau of Roads, United States Department of Agriculture, and the bulletins issued by A. S. Cushman have contributed materially to our knowledge of the causes of corrosion and its prevention. The preservative treatment of

1 Proceedings Engs. Soc. West. Pa. Vol. 25, p. 191.

structural materials, including by that timber as well as steel, has been brought to the attention of the paint makers of the United States by the widespread distribution of adulterated products by unscrupulous makers and drastic legislation inaugurated by certain states to prevent injury and loss to unsuspicious customers. The paint manufacturers of the United States as a matter of self-defense found it necessary to organize their Bureau of Promotion and Development which very shortly discovered the need for the treatment of the whole question from the standpoint of exact science. Its Scientific Section was organized in September, 1907, under Mr. R. S. Perry, Director, and has done most efficient work in the direction of systematizing and making exact our knowledge. The present Director of the Scientific Section is Mr. H. A. Gardner, well skilled as an analytic chemist and thoroughly competent for his position. Under his management and in line with the methods and plans adopted by Mr. Perry we may expect in the next few years exact information of much value both on the causes of corrosion and the means for its prevention.

There are three theories of a chemical nature which have been propounded to account for the corrosion of iron and steel; the carbonic acid theory, the hydrogen peroxide theory and the electrolytic theory. The latter is the most recent and has arisen in connection with the doctrine that all chemical action is ultimately to be traced to differences of electrical potential in the elemental ions. Now the science of pure chemistry as conducted in laboratories is one thing and the science of applied chemistry as conducted in the large uses of structural engineering is another. Paints compounded in accordance with the formulas of the laboratories have been known to fail utterly in field tests, while some pigments of demonstrated high value in actual use are worthless from the standpoint of theory. Truth is, the corrosion of iron and steel and its prevention is as much a physical as a chemical problem and a final theory must be built on investigations in both directions.

Preservative coatings for steel may be divided into two classes, metallic and mineral. In the former class protection is attained by chemical change in the outer surface of the material

itself or by the deposition of another metallic substance thereon. Steel may be Bower-Barffed by change in its outside skin texture under high temperature in the presence of steam which reduces it to black magnetic oxide, it may be covered with a copper coating by electrolytic action or by rolling processes, it may be galvanized by immersion in a bath of molten zinc, or, in accord with the most recent process, it may be Sherardized by the deposition thereon of metallic zinc abosorbed under high temperatures from an atmosphere charged with zinc dust. Such coatings are characterized by permanence and, where expense need not be considered, are ideal.

In the latter or mineral class of preservative coatings corrosion is prevented by physical applications which cover the surface but do not combine with the material itself though there may be a limited interpeneration of the fibres. Mineral coatings may be divided into two classes, paints and plasters. In the former protection is secured by the use of very thin films of pigments combined with binders of demonstrated elasticity and imperviousness to moisture, spread by brush, spray or other like means; in the latter protection is secured by the use of cements, etc., with or without combined pigments spread in relatively thick coats by trowel. Both of these methods have their value. We need to know where to paint and where to plaster.

And in connection with painting, it is very clearly made out that a pigment which is entirely suitable for inside wood work may be absolutely worthless for steel under any circumstances; also that a pigment which may be excellent on steel when exposed to heat and cold in a dry atmosphere may disintegrate speedily with ruin to the steel when exposed to moist salt air and strong sunlight along the seashore. Just as there is a time for everything under the sun, so also is there a place; and wisdom in painting consists in the ascertainment of the right place for each claimant to favour. The only thing certain today is that a permanent steel structure is no fit place for a poor or cheap pigment, or for a good pigment poorly applied.

These are but a few of the many problems with which the

user of steel has to do. Their solution is most worthy of engineering ability of no mean order.

Mr. R. B. Woodworth: One of the subjects I had in mind in the matter of road materials was the use of bituminous compounds for wearing surface. The first road of that kind I saw I think was in Kansas City where no one of the drives to West Park there was a fine uniform surface made from a compound sold by the Standard Oil Co., which was practically dust proof. These wearing surfaces have been introduced in several cities in the East, and I think it might be well to have a note in the minutes of this meeting to the effect that that is one of the subjects which might be considered in the discussion of road materials when the full paper comes up later.

Mr. E. K. Hiles: One feature in cities that comes up in connection with this subject is that of repairs of roadways. It seems necessary, or at least customary, to cut up our streets at frequent intervals and it has not been my good fortune to see any very lasting repairs made to such roads. We find the marks of the hole or trench very evident a short time afterwards. I do not know that this is altogether a matter of road materials but possibly it might be introduced in the later discussion.

Mr. S. E. Duff: That brings up something I have not heard mentioned yet, the foundation of a road. Is this discussion to be restricted to the wearing surface or are we going into the question of the foundation, the slope of the road, the proper shape of the crown and a great many other things that ought to come into the question of road building? I think we ought to call attention to those things to make our program complete.

Mr. A. E. Daum: Contractors are very often, owing to local conditions, permitted to use a native stone for top dressing of macadam roads, and this stone in many cases is soft and of an inferior quality. This has much to do with the rapid wearing of the surface. I, therefore, believe that while discussing the question of proper material for binder, that the quality

of stone or materials used for the top course in connection with a binder, should receive most careful consideration and investigation.

Mr. J. A. Ferguson: It seems to me that in studying refractory materials we ought to go one step further and study the subject of reinforced concrete throughout. This is rather a new material to be used in construction yet it is coming to be so universally used throughout the country that it is getting much attention from many good engineers.

Mr. S. E. Duff: I do not believe Mr. Asher touched on the subject of investigating the materials for fireproofing. I believe it is customary to leave the choice of the material itself to the manufacturer very largely and simply expect him to guarantee the structural results and of course the fire resistance. Perhaps we might be able to bring out something which would enlighten us all on the question of what we should expect or insist on in regard to the quality of the material itself regardless of its shape, size or peculiar arrangement.

Mr. J. A. Ferguson: I would suggest that those who want to read up on this subject get the reports of the government tests at St. Louis.

Mr. A. V. Bleininger: It might be well in this connection to point out two of the fundamental requirements of fireproofing materials. There are a few fundamental requirements which must be met and first of all the material, whatever it may be, must be able to withstand sudden heating and cooling without spalling or any other serious defects; secondly it ought to possess, after this heating and cooling, sufficient strength to support the load it is intended to carry. As regards concrete the properties of the aggregate used must be considered and the function of such additions as cinder. This raises the question whether or not the addition of such material is beneficial. We know that concrete in itself contains chemically combined water, which if it heated suddenly is expelled, giving off steam, and in some cases may cause rupture. This is a large subject which is not as simple as it appears and which it is difficult to discuss without experimental evidence.

MR. JONATHAN JONES: If the purpose of these papers is to present certain problems which the members of the Society are to investigate and perhaps gain some step toward solving, may I suggest that these particular problems are more apt to be solved by those who are commercially connected with them? We can be of more service to the community by investigating subjects like the two preceding, road and fireproof building materials, where there is an innocent purchaser who cannot make the investigation, but does need the information and the protection which a bulletin backed by this Society can give him; but in this matter of high refractories the persons most vitally concerned, the makers and users thereof, are earning their daily bread by attempting to solve the problems presented, to their mutual satisfaction, and since they have all the facilities and all the incentive I do not see that we can help matters much with the means at our disposal, however glad we may be to learn of what others are accomplishing when it is as interestingly presented as in the paper to which we have just listened on refractory materials.

MR. H. C. CRONEMEYER: I rather disagree with the gentleman who has just spoken. A great many of our members are necessarily interested, and are connected with concerns using these refractory materials, and if each one will relate his experience and tell what has been done and is being done in a distinctly engineering way the question of proper selection of materials would come very much to the foreground. The fireproofing question will be very interesting, and discussion will contribute largely to the proper selection of materials. Hence it appears to me that the discussion from the engineering side by this Society is very timely.

MR. W. M. JUDD: It seems to me that the engineer is very much interested in the problems relating to the higher refractories which have been discussed in Mr. Seaver's paper. It will seldom be possible for an engineer to make the investigations necessary for the solution of these problems, but it is important that he should be posted on the results of the investigations carried on by specialists so that he may select the

material best adapted to the work he is carrying on. As an instance of a question in every-day practice: What is the best brick to use in a boiler setting? Again, in coke oven construction, the newer type of rectangular oven calls for special qualities of fire brick to meet the special conditions under which the ovens are operated.

It seems to me, therefore, that the higher refractories as building materials are indeed worthy of consideration and discussion by this Section.

Mr. P. S. Whitman: I would like to ask Mr. Seaver a question in regard to the blast furnace. He mentions that the new type has a heavy steel shell and a thin lining of brick. It puzzles me in a general way to know why this is being done, why not use the thicker lining?

Mr. Kenneth Seaver: The successful working of the blast furnace depends in large measure on the proper maintenance of the lines. If the lining is so thin that it gets the effect of the water cooling fully and is of such physical structure as to withstand the abrasion, there is no change in the lining and there are maintained the theoretically perfect lines with which the furnace was designed. It is a gain in regularity of operation, which is the great desideratum. Of course as to just how great that gain may be few blast furnace men are yet ready to say; but such reports as there are have been remarkably satisfactory. I think that this is a fair statement. This method has been employed abroad for a number of years, but just how successfully I do not know. It is German practice I think, adopted with some modifications possibly.

Mr. H. E. Ashley*: I think it would be a good plan to have some one who is acquainted with the study of medicine discuss with us the sanitary conditions of streets in connection with the dust problem. I understand that a bulletin of the Department of Labor and Commerce states the deaths from tuberculosis among teamsters to be 25 percent, which can only be attributed to the dust which they breathe in their daily occupa-

*Assistant Ceramic Chemist, U. S. Geological Survey Testing Station, Pittsburgh.

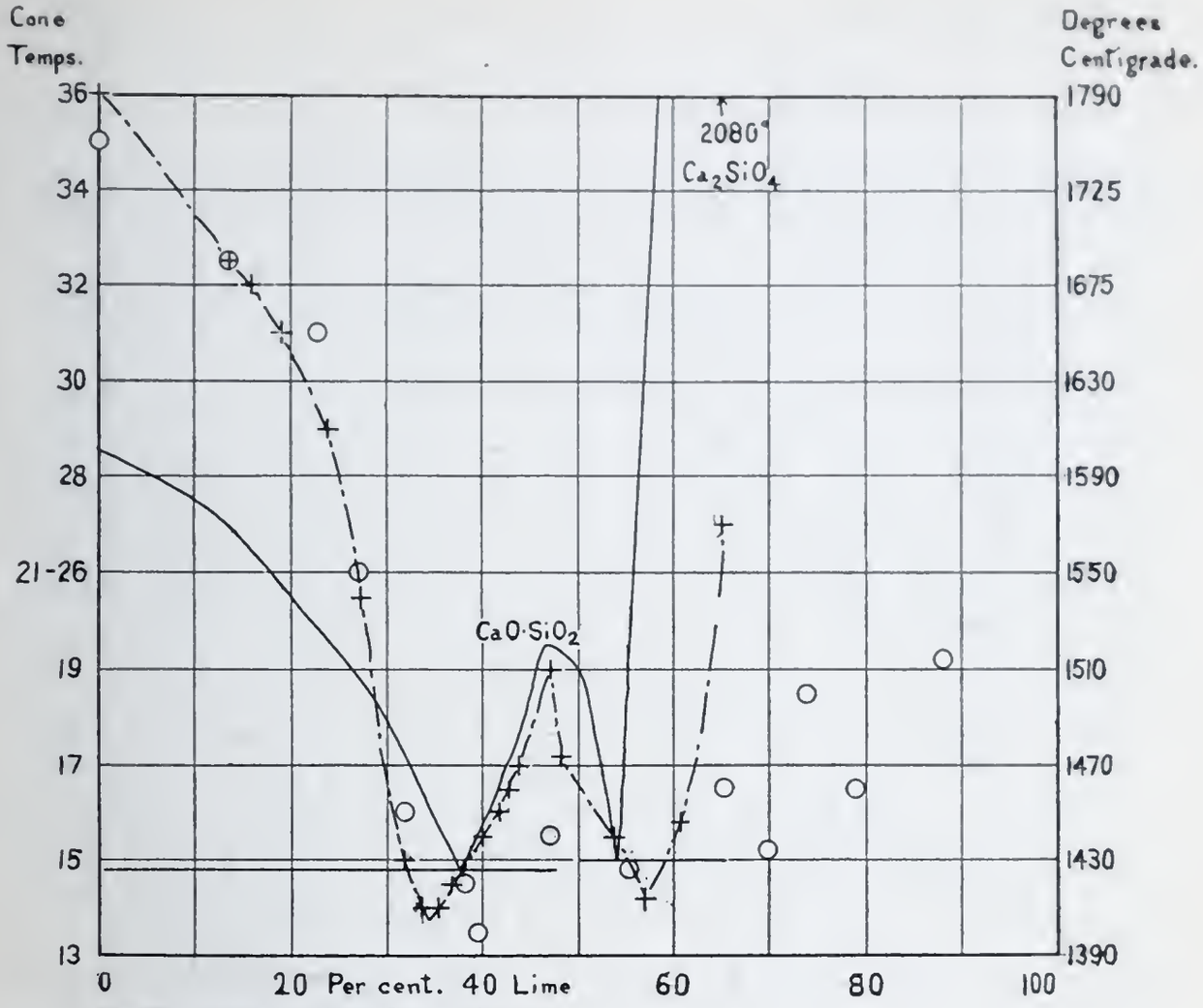
tion. That seems to me a very serious phase of the question. C. E. A. Winslow has reported to the Master Plumbers' Association that the air of sewers is purer as regards bacteria, than that of the street above.

Two years ago last autumn, Pittsburgh was a horrible place to live in. Day and night the air was filled with an exceedingly irritating and penerating dust from the streets. Every druggist displayed cough medicines. The people did not need medicines, principally; they needed clean air. To have clean air we must have streets that are easily kept clean. It is exceedingly important. It is one of the reasons why I live miles outside of the city. This condition exists in practically every city I am acquainted with.

In connection with the discussion of Mr. Seaver's paper, I have brought several diagrams illustrating the subject of refractories; in order that I might answer some of the questions asked members of the Society during the inspection trip made to the Testing Station last Saturday.

The following diagrams show the effect of fluxes. The first diagram, Fig. 1, illustrates mixtures of lime and silica. You are acquainted with lime-silica brick as a building material and its fireproofing properties. The ordinary lime silica brick contains not more than from 2 to 10 percent of lime, the melting points of which, given by the accurate investigations of Day and Shepherd are from about 1600 to 1550 deg. cent., if the mixtures were perfectly homogeneous. However, the lime is not homogeneously distributed through the brick, but is a binder which probably acts the same as a mixture containing a larger percentage of lime, that is having a softening point much below that of the brick taken as a whole. I have also put on this diagram the results of two other investigations, by Riecke, and by Boudouard. This gives an illustration of how the user of published data has to use judgment in considering the source of his information. Boudouard should have been considered as capable of doing as good work as Riecke, but his work varies much more from the exact work of Day and Shepherd than does that of Riecke.

The second diagram, Fig. 2. illustrates mixtures of mag-



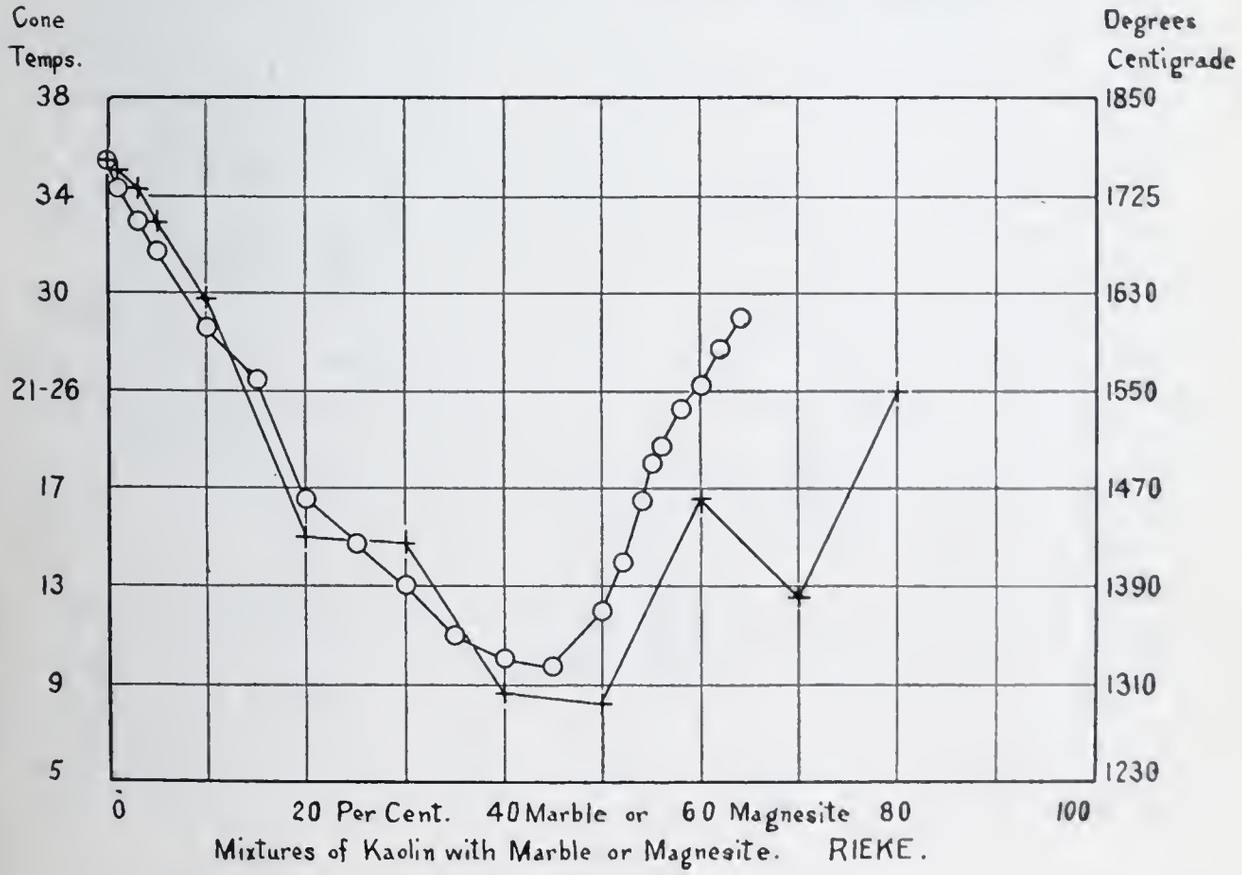
Melting-points of Lime-Silica Mixtures.

Full line, Day and Shepherd, Am. Jour. Sci., 22, 265 (1906).

Dot & dash, Rieke, Sprechsaal, (1907) No. 4.

Circles, Boudouard, J. Iron & Steel Inst., (1905) part I, p. 339.

Fig. 1. Melting Points of Lime—Silica Mixtures.

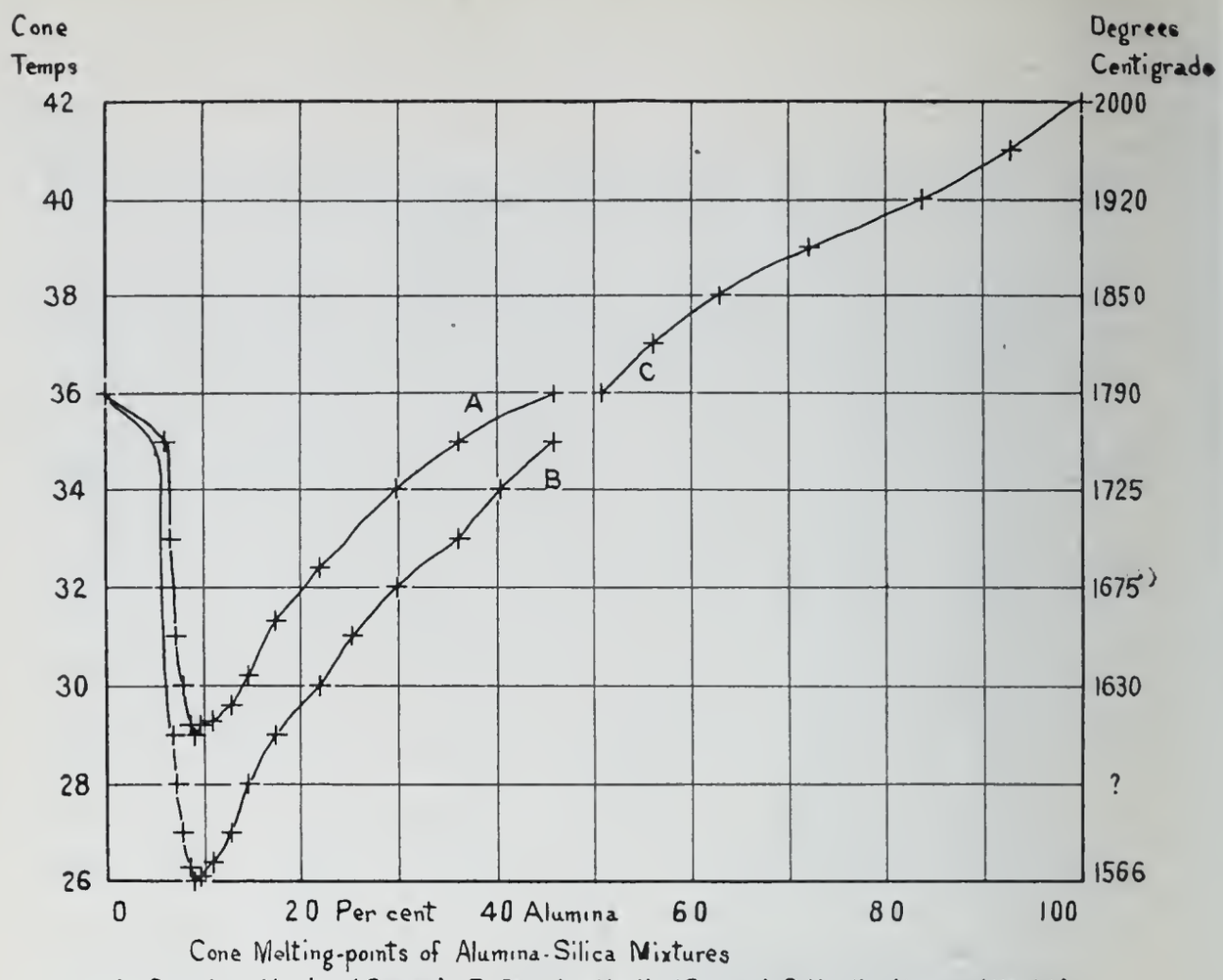


Mixtures of Kaolin with Marble or Magnesite. RIEKE.

Circles. Magnesite. Sprechsaal, (1907) No. 17

Crosses, Marble, " .(1906) Nos. 37-38.

Fig. 2. Mixtures of Kaolin with Marble or Magnesite.



Cone Melting-points of Alumina-Silica Mixtures.

A Quartz-Alumina (Seger). B Quartz-Kaolin (Seger). C Kaolin-Alumina (Hecht).

Fig. 3. Cone Melting Points of Alumina—Silica Mixtures.

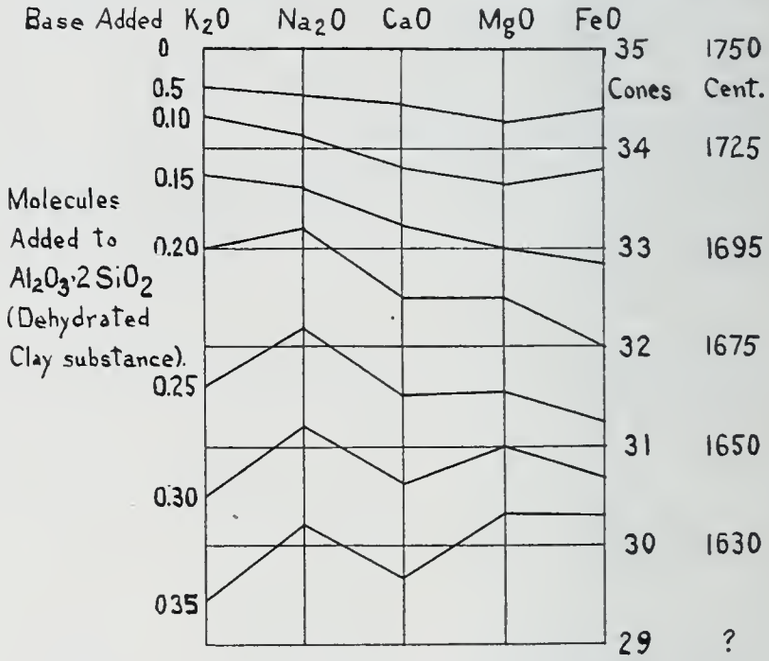


Fig. 4. Richter's Law: Effect of Small Additions of Fluxes.

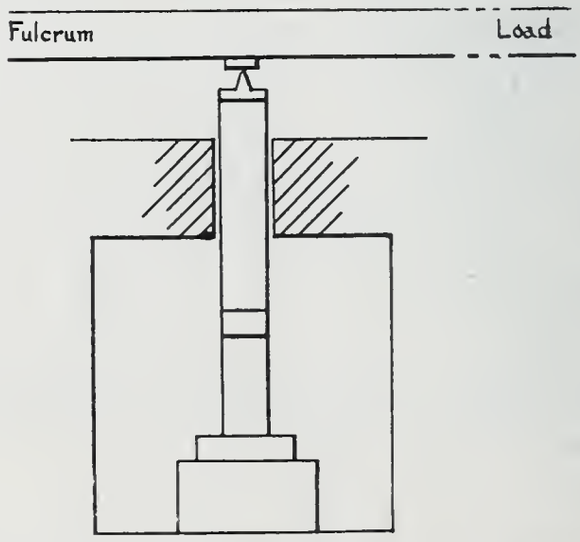


Fig. 5. Sketch Showing Interior Arrangement of Furnace for Load Tests on Fire-brick.

nesite and marble with kaolin, kaolin being taken to represent typically any clay. It is seen that as the amount of clay increases the refractoriness of the magnesite brick falls off. The same is true of the addition of lime.

The next curve, Fig. 3, illustrates mixtures of alumina and silica and is compounded from the work of several investigators. If we take the melting point of pure alumina, it is probably somewhere about 2000 deg. cent. Additions of kaolin to that bring it down to 45.8 percent alumina, at the composition of pure kaolin. Further additions of quartz being made, the melting point is brought down to the neighborhood of 1566 deg. cent. at 9.1 percent alumina, and then the least amount of silica raises the melting point rapidly to 1790 deg. cent., the melting point of pure silica. A silica brick is composed of silica grains with a certain amount of clay substance to act as a binder. We see that as the amount of clay is increased, the refractoriness rapidly falls off after passing perhaps 6 percent so that it is exceedingly desirable to have a silica brick very high in silica, or else have a clay brick.

Fig. 4 illustrates Richter's investigation on the effect of fluxes, either potash, soda, lime, magnesia, or iron, upon the melting point of a clay. The clay in the investigation was a pure kaolin, having a melting point of about cone 35. Taking the kaolin formula and adding 0.05 of a molecule of any one of those bases, a slight decrease in the melting point occurred. Further additions proportionally reduced it further.

The sketch shown in Fig. 5 will explain to some extent the work which has been done on fire brick at the Government Testing Station. The brick are placed on end in the middle of the testing furnace, which might be considered as a cubical chamber. On the brick to be tested is placed a half chrome brick and then a cylinder of clay and alumina passing through the roof of the furnace. On this is placed a knife edge, shown in Fig. 6, which carries a beam by which the load is applied. If we take the amount of alumina in the brick as one molecule, plotting as ordinates the equivalent of the various bases and as abscissae the equivalents of silica, a point is reached with about 0.25 equivalent of bases above which every brick tested at

1300 deg. with 75 lb. per sq. in. load failed and crushed, and below which every brick tested withstood the load, although shortening somewhat.

Another way of testing refractories under load was devised by Cramer, who made up a bar from clay 1 cm. in width, 2 cm. in depth and 20 cm. long, placing this in a kiln with supports 15 cm. apart. When subjected to heat these bars sagged down. With repeated burnings the bars went further each time. He found that a coarse structure opposed this sagging to some extent. Silica in some cases opposed this sagging. I conducted some bending experiments similarly; but used a larger bar, and in the firings subsequent to the first, put a load on the middle of the bar.

It proved a very satisfactory way of determining the load carrying capacity of those bars at high temperature for the

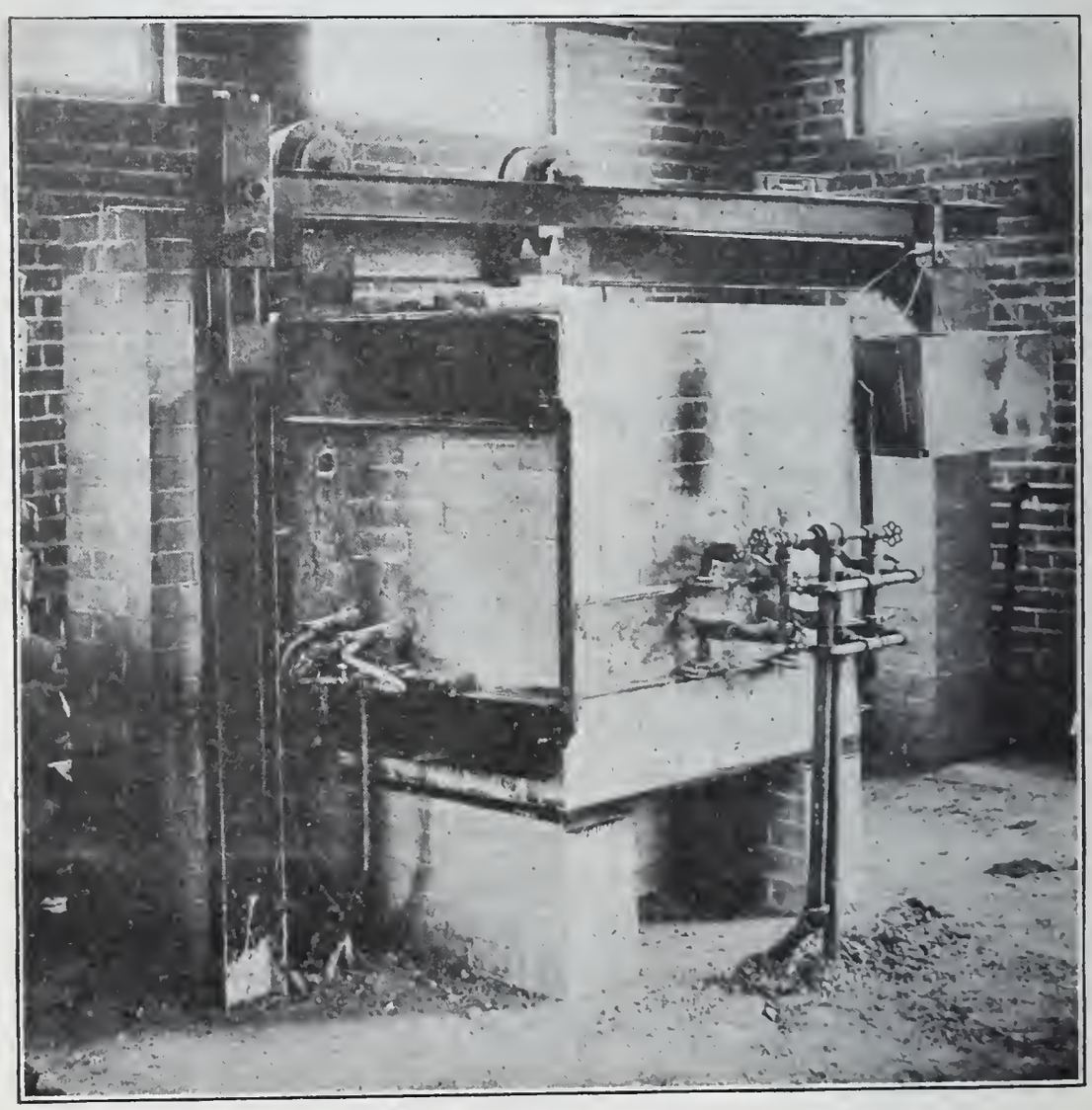


Fig. 6. Exterior of Furnace for Load Tests on Fire-brick.

Fig. 7. Behavior of Fire-brick Under Load of 75 Lb. Per Sq. In. at 1300 Deg. Centigrade.

particular purpose which I had. It would not take the place of this firebrick load test, however.

One thing that was brought out very decidedly by these tests of the loaded bar, was that the method of manufacture, that is the human equation, is exceedingly important. For example, the amount of water used in making up the brick. The more dense it can be made in its raw state, that is before it is fired, the more satisfactory will be the results as to load carrying capacity.

Fig. 6 shows the exterior of the furnace for load tests on firebrick, and Fig. 7 shows the successive degree of shortening and failure of different firebrick. Brick No. 19 has shortened somewhat, but stands up well. Brick No. 9 has failed. The pushing of the top to one side is not due to bad placing of the brick, but to the tendency of the pyramids of fracture to slide past each other. Brick 27 shows the same tendency modified by a greater degree of viscosity of its material.

There is one thing more that Mr. Bleininger has found concerning the effect of a porous structure. There is absolutely no connection between the amount of water absorbed and the shortening or complete failure of the brick.

In regard to fireproofing and boiler settings the porosity of brick is of considerable importance, as regards preventing the transmission of heat, whether outward from a boiler or inward

as in the case of a piece of fireproofing. At ordinary temperatures an air space is more efficient in preventing the flow of heat than is a brick. But from a temperature of only about 100 deg. cent.; i. e., from the boiling point of water, the radiation of heat through an air space is greater than is the flow of heat through a brick, and further the radiation increases with the fourth power of the temperature. It happens in some kilns that the amount of heat lost in burning the products will vary from 50 to even 75 percent of the total amount of coal put into the kiln. In the case of an ordinary boiler setting, it is a matter of great importance that a very porous brick be used, perhaps as soft burned a brick as can with safety be used around a boiler, or a brick in which saw dust or anthracite coal has been mixed so that when this burns out it leaves a larger volume of air cells than usual.

Mr. R. B. Woodworth: I hope when the full paper on timber is presented at the meeting of the Structural Section someone will tell us the relation which exists between the texture of the timber and its structural qualities. When timber is examined under the microscope, white oak, for example, is almost impenetrable to light. Other timbers of cheaper grade can be examined by transmitted light without any difficulty. There is a fineness of grain and texture due beyond doubt to the rate of growth, the arrangement of the cells and the circumstances which have to do with the wood considered as a plant. One of the questions especially connected with low grade, as well as high grade timbers or timbers of low strength and high strength, it seems to me is what effect looseness of texture and rate of growth has on the strength of the timber itself.

Prof. Martin Hokanson: The speaker on steel mentioned ingot iron as being a material that could resist corrosion, and said that this form of iron, pure iron, already had a year's use. I think it is difficult to draw a definite conclusion in regard to the corrosive qualities of the material after an experience of only one year. I had the opportunity a short time ago to test some wrought iron on a suspension bridge up in Canada which had been in over 60 years, and I could see hardly any corrosion

on it. Mr. Cushman's argument that the corrosion depends upon electrolytic action of the different elements, is rather undisputed today among those who are investigating the subject of corrosion, and I think that we will see more and more that we have to look at the elements present in the iron. The less elements there are present in the iron, the less chance we have for electrolytic action. It may be that some elements are inert and can be present without adding to the corrosion; some other elements I am sure accelerate corrosion. We have seen so far that manganese accelerates corrosion quite considerably. On the other hand it seems that nickel retards corrosion, forming electric couples which retard the iron from going into solution. The protection of steel is, therefore, to be sought first in the material of the steel, and second in the protection of the steel, as the speaker referred to.

In the protecting of steel I would like to say that the American Society for Testing Materials Committee, in their report last year referred to chromates as being the best materials so far known to prevent corrosion. These chromates in a proper vehicle like linseed oil, would be the solution.

The speaker mentioned a formula for computing the strength of steel based exclusively on the chemical constituents of the material. To be able to do this, I think it is necessary to know the heat treatment and the mechanical treatment the steel has undergone, hence it is hardly possible to determine the ultimate strength or the elastic limit from its chemical composition alone.

The shearing strength of steel the speaker gave as 75 percent. Results of tests usually show about 80 percent. The speaker also mentioned something in regard to the ultimate strength intension and in compression, and stated that these were equal. We really do not have any ultimate strength in compression, there is no absolute failure in a ductile material. The ultimate strength of steel in compression is really the elastic limit and the elastic limit in tension is usually taken to be about equal to that in compression, which is very nearly true.

In regard to the different strut formulae in use, I may say so far as I have investigated, the subject which covers small

sections and lengths, all with less than 100 000 bearing capacity and should, therefore, not count for much; but so far as these small tests go, the Johnson's "straight line," or the Johnson's "parabolic" formula, is about the closest to the actual tests. Johnson derived these formulae from results of actual tests.

Mr. R. B. Woodworth: Just a correction. My recollection of what I said in regard to ingot iron was that it had been on the market about a year. I may be misinformed as to that, but my statement was to the effect that there had been put on the market a material of high pureness known as ingot iron, which contains but traces of manganese, and whose advocates claim that in it corrosion has met its Waterloo.

THE USE OF GEOLOGICAL SCIENCE IN THE PETROLEUM AND NATURAL GAS BUSINESS

By Frederick G. Clapp *

Ever since deep wells were first drilled for oil and gas there has been a difference of opinion between geologists and operators as to the practical value of geology in the oil and gas business. While geologists have proposed various theories for the origin of bituminous substances and for their relations to the rock formations, and have in many cases shown a direct structural relation, the oil and gas men, on the other hand, have mostly maintained the view that the success of wells was largely or entirely a matter of chance, and that modern science could give them no aid. Within the past few years there has been a tendency towards harmony between the two classes of men; the more progressive operators and companies now admit the considerable value of geology to them, while geologists, on their part, admit their own limitations and the limitations of the science at present, while not withdrawing at all from the claim that geology *can* and *does* locate oil and gas deposits. This science is progressing year by year, the apparent backwardness of geologists in offering a full explanation of the phenomena and of unsuccessful predictions in some cases being due to the comparatively slow progress of geology as compared with the great rush of oil development. In view of the considerable difference of opinion which still prevails, it may be profitable for this Society to take a careful estimate of just how far geology has gone and can go in solving this—one of the most perplexing engineering problems of the day.

The question whether geology is of value to the oil and gas operator can be answered affirmatively, viz.: it is of very great

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* Consulting Geological Engineer, Pittsburgh.

value to him. That is, geologists are now locating wells successfully, and they are likewise warning intending investors and operators away from places where oil and gas are absent. Failures are few when drilling is based on geological predictions. Some failures still occur, however, because science as yet does not enable us to look from the surface into a deeply buried stratum of the earth and examine its internal structure.

A few uninformed persons still cling to the time-worn, erroneous idea that geologists make their interpretations through the use of some mysterious faculty or of unreliable instruments of the divining-rod type. These instruments, ranging in character from slender peach branches to complicated magnetic and electrical mechanisms, have been used by quacks and imposters for decades, but their use is not sanctioned by reputable geologists or engineers. All kinds of divining-rod instruments depend for their operation upon the conscious or unconscious, intentional or unintentional, will of the "oil-witch," or person employing them, by working through slight movements of his muscles, invisible to bystanders. The belief in the value of such instruments rests on the mistaken assumption that some kind of magnetism exists between petroleum and the nerves or mind of the "oil witch." Of course all members of this Society understand that such contrivances are humbugs; it is sufficient, therefore, to merely mention that modern science knows of no such magnetism, and is authority for the statement that it does not exist. The use of divining-rods has been investigated by the United States Department of Agriculture and the United States Geological Survey and all such inventions have been proved to be without value.

Many of the persons who use divining-rods or similar instruments are entire frauds; a few of them are men of a deluded mind, who honestly believe that the action of their instruments will reveal the presence of oil. Some of them, good guessers who have had practical experience in the oil business, may possibly have even hit upon the location of pools, in certain cases, with the aid of their contrivances. But no person using any of these instruments is to be depended upon for the location of oil or gas; since the very fact that he believes in and uses a

divining-rod instrument is proof, either that he lacks a fundamental knowledge of geology or that he is an intentional imposter. It is interesting to note that in most of the oil fields of the country oil-witches have been responsible for many dry holes and consequent loss of money to easily deluded wild-catters.

A certain class of persons, who understand the unreliability of the divining-rod and of oil-witches, have believed that geology and geologists belong in the same class. This is a mistake. A geologist or a geological engineer is to oil and gas development what a consulting engineer is to any important branch of engineering construction. As the province of the consulting engineer is to examine all problems concerning a proposed building, bridge or reservoir, to determine its feasibility and cost, and to make such recommendation as may seem important in the successful prosecution of the construction work, similarly, the province of the consulting geologist or geological engineer is to examine the character of mineral lands and to study the strata of the earth, any available records of wells, and the geographical and geological relations of neighboring pools, to determine the value of the territory for oil, gas or other minerals, the best locations, the availability of the territory for profitable exploitation, and to make such recommendations regarding development as will enable his clients to profit by their ventures.

In making his determinations and recommendations the geologist or geological engineer uses no mysterious methods. His work is based upon such knowledge of the formations of the earth as is acquired by his studies and education, and upon the practical experience which he has gained in various fields. Men engaged in the gold-mining business now understand that a mining geologist is of the greatest service to them, because one who understands the natural laws under which gold exists in the veins or placers can make an examination and report which are inestimable value to operators and intending investors. Just so in the oil and gas business; a geologist or geological engineer who understands the relations of oil and gas to the strata in which they exist can go far towards locating

pools and wells successfully, and can frequently save thousands of dollars to operators and investors by warning them away from barren territory. The real economic value of geology is evinced by the fact that some of the largest and most progressive oil and gas companies in the world have had geologists in their employ for years. The term "geological engineer" is more recent, and means that the geologist combines with his knowledge and experience the practice of advanced engineering methods, and of surveying and mapping. In most fields it is necessary to obtain the elevation of rock outcrops in order to determine the "lay" of the formations and therefrom find the favorable and unfavorable portions of the territory.

While the geological engineer does not use nor sanction the use of any such instruments as "divining-rods" or kindred "fake" contrivances, he does, however, make full use of the best engineering and surveying instruments obtainable; and he makes particular use of the easily portable and pocket forms, with which rapid determinations can be made. He uses the aneroid barometer in getting approximate elevations of rock outcrops, the hand level for more exact elevations, with reference to known bench marks, and the stadia transit or level when careful or numerous elevations are necessary. He uses the clinometer for obtaining the rates of dip of the strata, the compass for getting bearings and the direction of certain outcrops or wells from known points. He uses the pedometer or the stadia to obtain his horizontal distances, according as approximate or more exact measurements are needed. Frequently pacing must be resorted to. When an accurate base map is not available, from which to make calculations, he uses the plane-table and stadia-alidade in preparing such a base map.

In his determinations the geological engineer makes traverses in various directions across the territory and for some distance surrounding it; and he records the character, position and level of all geological outcrops graphically in his note-book. Frequently visits are made to neighboring oil and gas fields for the correlation of geological conditions between them. Levels are obtained of all wells and drill holes, and careful comparisons are made of the strata found in them. All rail-

road, quarry and mine sections are studied to determine the directions and character of the variations in strata and their dip. Any existing wells in the vicinity or in similar positions geologically are studied with reference to the character and value of their production. Analyses are made when necessary. In fact, all evidence of any possible value is obtained. All the facts, geologically and otherwise, are then considered in relation to each other, and therefrom the determination of the favorable and unfavorable portions of the territory, the limitations of each, and the best locations, are arrived at.

In making his interpretations, the geologist recognizes the difference which exists in the relation of the quality of oil to the geological conditions in different fields, and even in different portions of the same field and in different strata. In no two pools are conditions exactly the same, but differences exist which are caused by the difference in geological conditions. The geology of a particular pool or of a particular portion of a stated pool is studied to determine local differences and their effect on the accumulations of oil and gas. Certain underlying causes and their results always exist, and to these are added the consideration of such local causes as may be found during the examination.

There is no one condition which determines the location of oil and gas pools; on the contrary, there are many conditions, often complicated. One of the most important conditions is the presence of formations, or "sands," of such character that they can hold oil and gas, and this factor is carefully considered by the geologist. The "lay" of the formations, the nature of their anticlinal, synclinal, monoclinal or quaquaversal structure, also is important, and in a known field the interpretation of this feature perhaps goes farthest towards determining the location of pools or of wells. It is a mistake to suppose that all parts of an anticline are considered as favorable, or that all parts of a syncline are considered as unfavorable. On the contrary, there are certain parts of anticlinal and certain parts of synclinal structures, determinable by geological examination, which, when present, will hold oil or gas, provided that all internal conditions are favorable. Conversely, there are certain

parts of synclinal and certain parts of anticlinal structures which are always barren of oil and gas. There are intermediate favorable structures and intermediate unfavorable structures, which are distinguishable; and there are some structures that cannot be distinguished in the present stage of the science.

It should not be supposed that any geologist or geological engineer claims to be infallible. On the contrary, the most experienced of them realize that there are some cases in which no one can make a determination, and there are some cases in which mistakes have been made. Mistakes by an experienced geologist are few, however. A geologist, like a physician, knows that there are occasional cases that are beyond his ability to solve in this age, but such cases do not condemn the science. If an occasional patient dies, neither the physician nor the science of medicine is universally condemned; no more should a single dry hole located by geology stand as a condemnation against geological science. What such a dry hole does mean is that the most favorable location in a certain territory has been tried and found barren of oil or gas, and this fact, combined with a knowledge of the geological structure, is of immense value in the next step taken in the development of the territory.

Every year thousands of dry holes are drilled in the United States alone. In fact, 4013 wells, or about 23 1-2 per cent. of the wells drilled in the country in 1909, were dry, according to the Oil City Derrick. A large proportion of the dry holes drilled in the past few years could have been prevented had a careful previous geological examination been made and taken advantage of. Moreover, it is safe to say that many pools that have taken decades to discover could have been predicted years before had a thorough geological examination of the surrounding territory been made with that object in view.

To the statement, sometimes made, that geology has never located an oil pool, it can be answered that geology has located many oil pools. Among those best known which have been located by geologists are the Mount Morris-Mannington pools of Pennsylvania and West Virginia located by Dr. I. C. White. In hundreds of cases pools have been extended on the basis of geological examinations.

Right here I wish to interpose a word for the men and the theories which helped geology to rise from the standing of mere theory to a place of practical usefulness in the oil and gas business. Since 1859 various geologists and others have published papers attempting to solve the problem. Among others, T. Sterry Hunt (1859 and 1863), E. B. Andrews (1861) and Hans Hoefer (1876) long ago recognized certain general relations of oil and gas pools to the anticlinal structure of a region. It remained for Edward Orton and I. C. White, however, to bring the anticlinal theory before oil and gas men in such a way as to force a measure of belief in it. Later investigations have expanded and modified the theory and made its application more practical to the operators, but much of the credit belongs with the early investigators

This anticlinal theory was, in brief, that oil and gas were originally widely disseminated throughout the formations in which they are found, or in contiguous formations, and their segretion was believed to be due to the different specific gravities of oil, gas and water. If a porous stratum contains these substances, when it is tilted by geologic causes, they will arrange themselves according to specific gravity; the gas, being lighter, will be driven into the higher parts of the stratum (towards the crest of the anticline), the oil will be floated on top of the water, while the water occupies the lower portions of the stratum (those nearest the syncline).

In Western Pennsylvania and northern West Virginia these accumulations, as is well known, take the form of belts approximately parallel with the geologic axes, in a general northeast-southwest direction; but the form and direction of the pools in other fields might be very different and still adhere to this theory of accumulation.

In practice, however, the anticlinal theory frequently did not meet expectations. Operators, after making careful locations based upon this theory, were frequently rewarded only by dry holes. The successes, overshadowed by the fancied failure of the theory, were lost sight of by practical oil men, and thus the theory fell largely into disrepute for a time. The excellent reports of the United States Geological Survey and the various

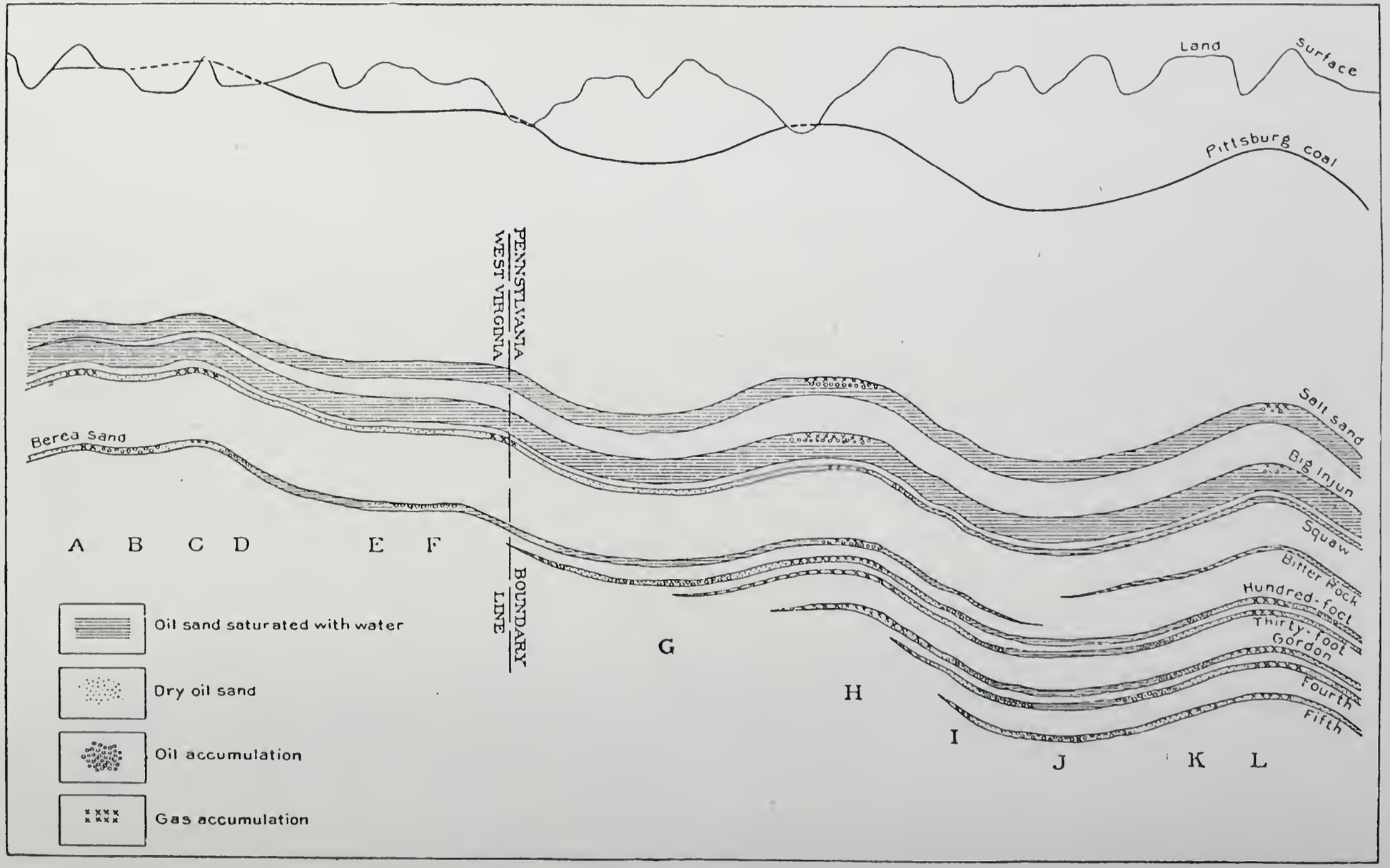

Fig. 1. Section of oil sands showing occurrence of oil and gas (according to Class *A2*) in Pennsylvania, West Virginia and Ohio (after Griswold).

state geological surveys contained references to the theory, and each writer tried to show the geological relation of certain fields in the particular territory covered. In many cases they were successful, and in all cases the major axes were found to correspond in a general way with the main anticlinal and synclinal axes. Many of the gas pools corresponded closely with the crests of anticlines and seemed to prove the theory. Other cases prevailed, however, in which the relation was less striking and some in which no relation could be determined.

The limitations, like the original theory, were imperfect in their application. They have been added to and revised by various geologists until now little is left of the original "anticlinal theory." However, great advances have been made consequent upon the detailed mapping of the geological structure by government surveys and private geologists. While we have not yet reached the state where a production can be located every time, we may truthfully assert that geology can now save a large proportion of dry holes. Moreover, much of the territory held for years by oil and gas companies has been shown to be not worth paying rentals on.

I prefer to use the term "structural theory" instead of anticlinal theory, for the relations which the accumulations of oil and gas hold to geology within certain limitations, even where no definite anticline or syncline exists. The theory, as I understand it, is as follows: Through some means or other, by organic or inorganic agencies, or by both, the petroleum and gas have gotten into the sandstone or limestone formations in which they are found. The deposits may have originated through the decomposition of plants and animals which lived millions of years ago on an ancient sea bottom, as the adherents of the organic theory claim. Or they may be the product of chemical action on carbides of iron or other substances existing under a state of potential fusion deep in the earth, as a few of the leading geologists of the world, adherents of the inorganic theory, claim. Or certain petroleum deposits may be of organic, and certain deposits of inorganic origin, which is a conservative opinion held by some modern thinkers.

We have not time in this paper to discuss the merits or probabilities of either of these theories of origin. Whichever one is true, the oil, gas and salt water entered the formations ages ago. Assuming that the sands were approximately horizontal at the time the oil and gas entered them, the substances must have been at first very widely diffused in the rocks. Such is true at the present time in some sections of the world, notably in several counties in western West Virginia fronting on the Ohio River, where only small quantities of oil and gas, to slight for profitable development, have been found by the drill. The dip of the rocks there is very slight.

Where the beds have been moderately folded, however, by earth movements, as is the case throughout the Appalachian region and in most of the other oil fields of the world, the slope and the changes in dip have enabled the oil, gas and water to separate out according to their relative specific gravities. This separation and concentration may have been assisted by rock pressure, hydraulic pressure, seepage, capillarity, molecular attraction, internal heat, or other causes; but whatever causes prevailed, the law of gravitation, being ever operative, must be considered of first importance, and the separation and subsequent accumulation was in the order of the densities of the substances. Sometimes the pools occur at the top of anticlines, sometimes lower down on them, sometimes in synclines and sometimes merely on monoclines. But on a stated anticlinal, monoclinal or quaquaversal structure, the gas is normally nearest the top, the oil lower down, and still lower is the salt water, if it be present. (See Fig. 1).

One of the mistakes of the earlier geologists and oil men was the assumption that surface formations are universally parallel with the oil sands. This is true in many fields, but in others it is far from being so. For example, the Clinton sand in southern Ohio is not even approximately parallel with any surface formation; but the interval between the Clinton and the surface strata increases towards the east at a rate ranging from 30 to 100 feet per mile, thus bringing the Clinton rapidly to a great depth.

With the assistance of a few well records within and near any locality, where development has been commenced or testing done, it is possible to work out the structure and "lay" of this sand to a fair degree of accuracy. This is done by first making a contoured structural map of some surface formation; then the exact intervals from this bed to the Clinton sand are found in whatever wells have been drilled to this sand in the vicinity, and a convergence map is prepared on the same scale. This was

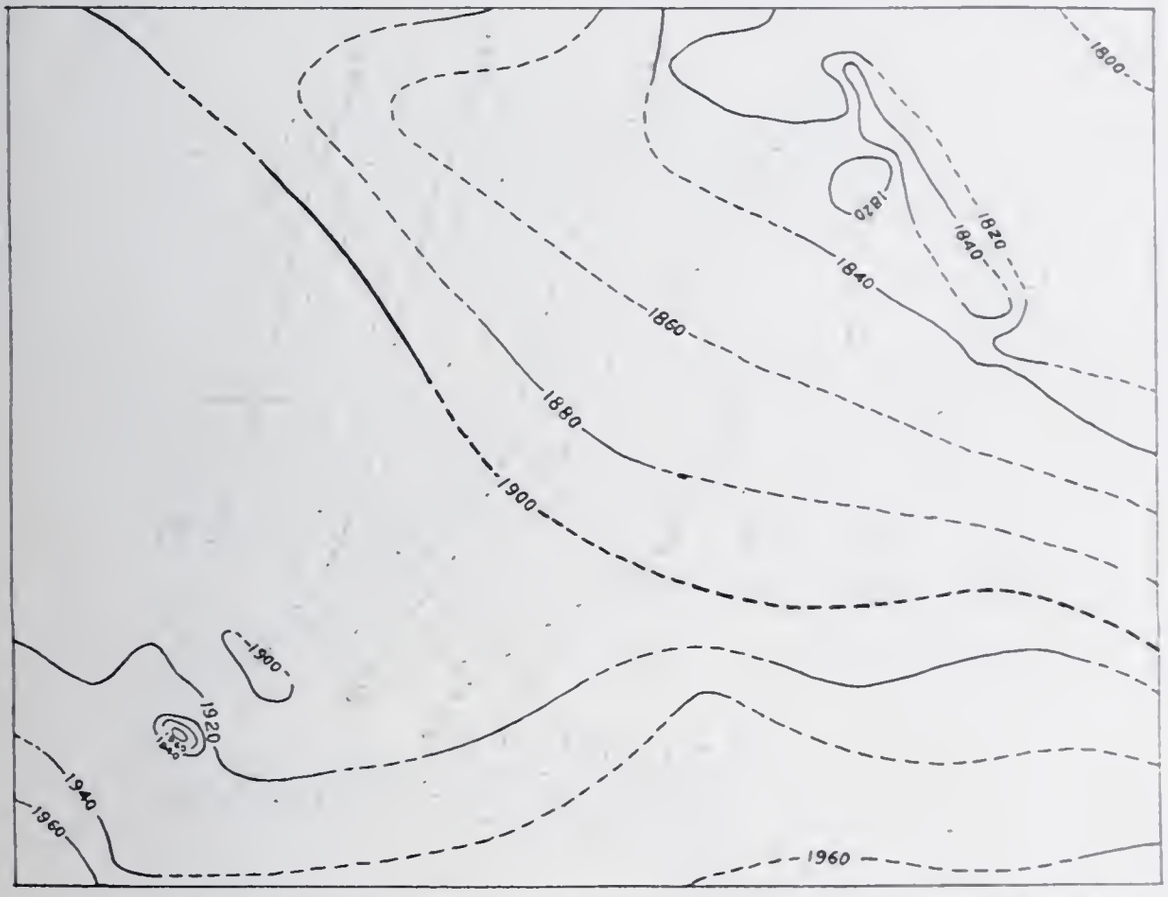

Fig. 2. Example of convergence map, from Bulletin 300, U. S. Geological Survey, showing change in intervals between Pittsburgh coal and Gantz sand in a typical area in southwestern Pennsylvania.

first done, so far as known, by the author of this paper in the Amity, Pennsylvania, Geological Folio, and in Bulletin 300 of the United States Geological Survey, in 1907, and the name *isochore lines,* meaning lines of equal interval, was given to the contour-like lines denoting the convergence (See Fig. 2).

In the Amity region in Washington County, however, the interval represented was that between the Pittsburgh coal bed and the Gantz (Hundred-foot) sand, the Clinton sand never having been reached by the drill so far east. In Bulletin 318

of the United States Geological Survey the same method of representing convergence was used by W. T. Griswold, who applied the simpler and perhaps preferable name "Convergence Sheet" to maps of this type.

In preparing a map of the structure of the Clinton sand and of the formations below the Big Lime in southwestern Pennsylvania, and of certain other formations, a convergence sheet must be prepared. From a careful comparison of this with the

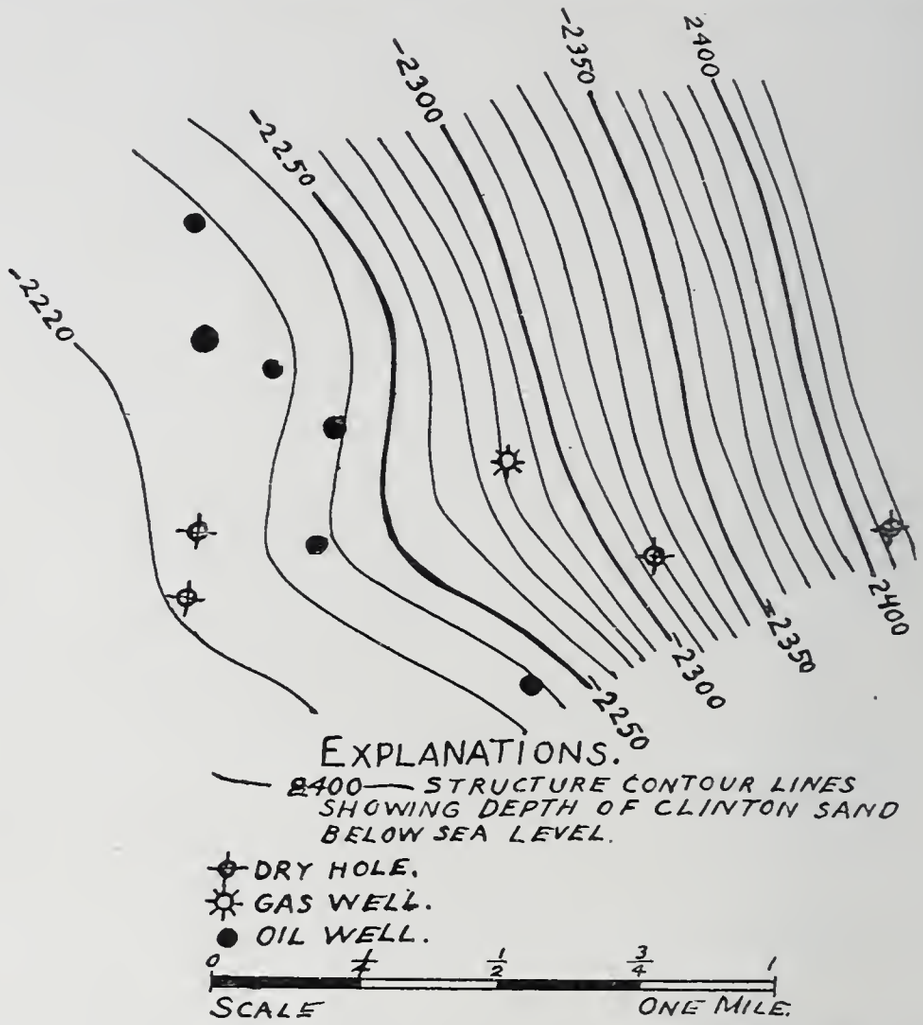

Fig. 3. Structure contour map illustrating the occurrence of oil (according to Class *A3*) in the Clinton sand, in a small area in southern Ohio.

contour map showing the "lay" of any surface formation, the "lay" or geological structure of the particular sand is calculated. In practice the finished map always shows that the structure bears a definite relation to the occurrence of gas and oil. The direction of the extension of the field can therefrom be predicted with a good degree of certainty; or, if there has been no deep sand development, the locations of producing wells can be

predicted with a fair probability. Fig. 3 is a map of the Clinton sand in a small area in southern Ohio, the structure having been determined in this manner. It will be noticed that the positions of the oil development correspond with the strike of the sand, and that the productive wells lie on the outer edge of a slight structural terrace.

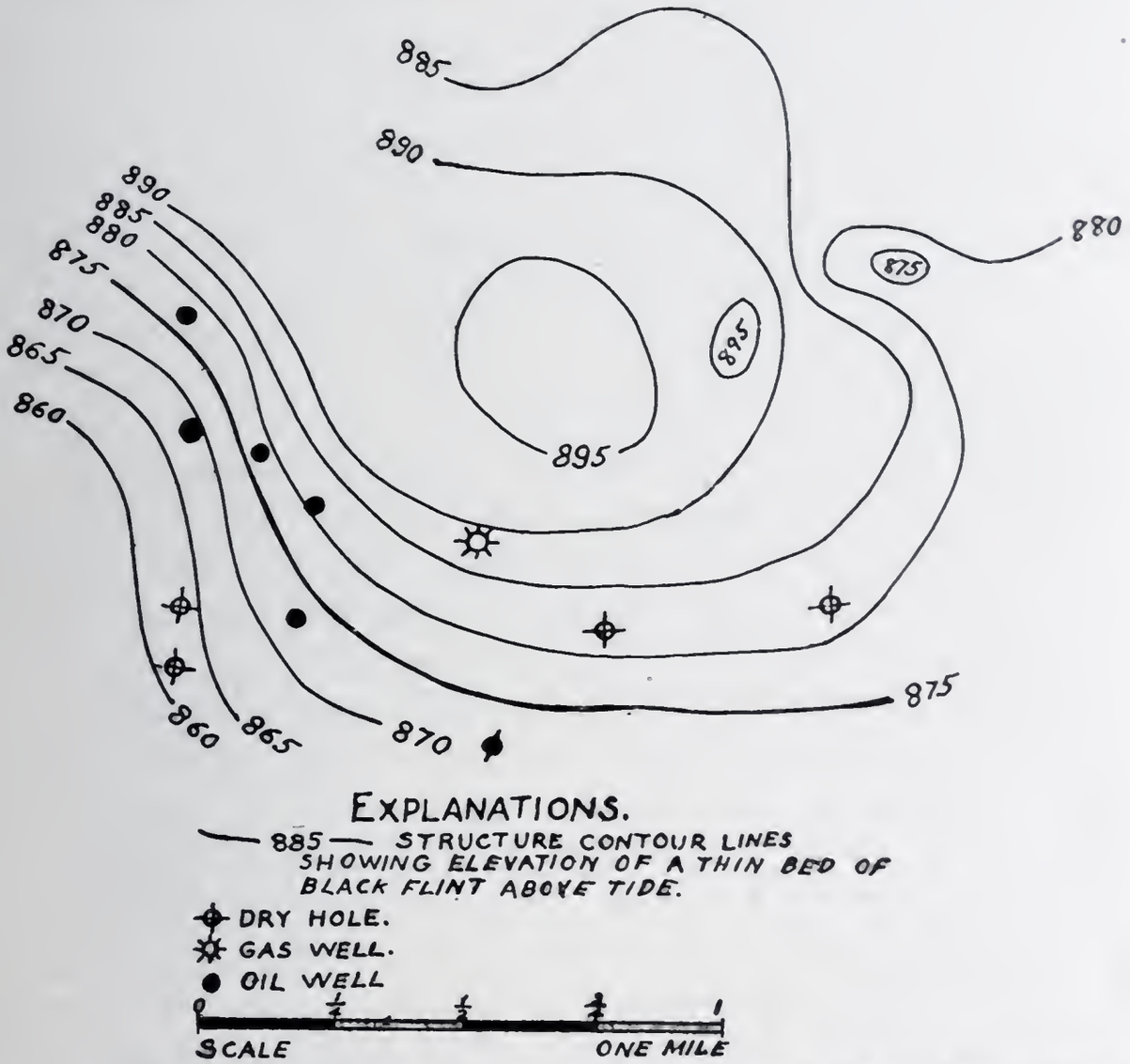

Fig. 4. Map showing the geologic structure of the surface strata in the same area as Fig. 3. (Fig. 3 was calculated from this by the use of a convergence map.)

Fig. 4 is the surface structure in the same locality. Such convergences in stratified formations are due frequently to unconformities caused by erosion of a stratum before the overlying one was deposited. That is what has happened in southwestern Pennsylvania, and explains why the red shale and Big Lime of the Mauch Chunk and Greenbrier formations disappear

to the west, and the Salt sand (Pottsville) rests directly on the Big Injun (Pocono).

The geological engineer must pay very careful attention to these unconformities. They are sometimes interpreted by careful study of the outcrops of the formations where they appear at the surface at distant points, as in the flanks of the Allegheny Mountains, in some of the deeper valleys of Chestnut Ridge, in northern Pennsylvania and in southwestern Ohio. The common and most accurate method of determining them, however, where local well records are available, is by careful study of such records. The elevations of the wells, with reference to sea level, and to some easily identifiable surface stratum, like the Pittsburgh, Washington or Upper Freeport coal, the Ames, Vanport, Cambridge or Niagara limestone, the Mahoning or Pottsville sandstone, are determined, and therefrom the convergence maps can be calculated. The whole process is the correlation of available geologic data, well records and engineer's levels.

In geology the methods of determination differ according to the locality and the nature of the problem. For instance, the methods used by a field geologist in tracing out and valuing a gold quartz vein would not be at all applicable to a coal mine examination. The methods of prospecting vary according to the mineral which is being sought. Similarly, in the oil and gas business, the methods of geological field work are different in the California fields from what they are in Pennsylvania, and still different in Louisiana. The methods used in the northern Louisiana fields are different from those in southern Louisiana, because the geology of the fields is different. At the same time, the methods used in Pennsylvania are usually applicable in all the oil-producing States east of the Mississippi and to Oklahoma and northern Texas and many of the Western fields.

In order to illustrate the differences in geologic conditions, the writer has made a tentative classification of oil and gas fields based on their geologic structure. The classification is not by any means perfect; and has not yet been formally accepted by the geological societies. It is given here to show that deposits of oil and gas can be grouped into classes, each division of which follows a special rule of structure, and all of which have

certain aspects in common. The classification proposed is as follows:

CLASSIFICATION OF OIL AND GAS ACCUMULATIONS

A. WHERE ANTICLINAL AND SYNCLINAL STRUCTURE EXISTS.
- *1* Strong anticlines standing alone.
- *2* Well-defined anticlines and synclines alternating.
- 3 Monoclinal dips with change in rate of dip.
- *4* Terrace structures.
- *5* Broad geanticlinal folds.

B. DOMES, OR QUAQUAVERSAL STRUCTURES.

C. SEALED FAULTS.

D. OIL AND GAS SEALED IN BY ASPHALTIC DEPOSITS.

E. CONTACT OF SEDIMENTARY AND CRYSTALLINE ROCKS.

F. JOINT CRACKS.

Class *A.* WHERE ANTICLINAL AND SYNCLINAL STRUCTURE EXISTS.

This is the type of oil and gas accumulation with which we are most familiar. It includes a large majority of the known oil-fields of the world. The Appalachian, Mid-Continent, Illinois, Indiana, Wyoming, Montana, Colorado, northern Louisiana, nothern Texas, and some of the California fields in this country, and the Russian, Austrian, Burma and Borneo fields in the Eastern hemisphere, all belong to this class. This is divided into five sub-classes, in order to distinguish between various structural relations in which oil is found in connection with anticlines and synclines.

1 Where Strong Anticlines Exist Standing Alone

In this division are included fields that bear a direct relation to very pronounced uplifts, easily recognizable, and which constitute a marked topographic and geologic feature of the region. The best example known in the eastern fields of the United States is the famous Eureka-Volcano-Burning Springs anticline in West Virginia, which is 25 miles in length, ranging in direction from North 10 degrees West to North 20 degrees East, and being from an eighth of a mile to half a mile broad on its flat crest, and having side-dips of from 20 to 60 degrees. This is one of the earliest recognized anticlines in the country, and probably has had as many wells drilled on it as any other. It has

been described by White, Andrews, Evans and others. Some of the California fields having sharp anticlines probably belong in this sub class.

2 Where Well-Defined Alternating Anticlines and Synclines Exist.

This is really a composite of sub-class 1. (See Fig. 1). It includes the entire Appalachian field in Pennsylvania, West Virginia, eastern Kentucky, southern Indiana and Illinois, the Oklahoma fields, the Caddo field in Louisiana, the north Texas fields, and those of Colorado, Wyoming and Montana.

The Caddo field has nothing in common with the Beaumont and Jennings fields and other fields of the Coastal Plain of Louisiana and Texas, but it is very similar in structure to the fields of Pennsylvania, West Virginia and Illinois. The proper structure in northern Louisiana is afforded by the Sabine uplift. The final distribution of oil and gas in the Caddo field is due to slight anticlines and synclines and to differences in porosity of the Upper Cretaceous formations which exist there.

Several of the oil fields of California also belong in this class. For example the Coalinga field and the Los Angeles field (according to Eldridge, Bull. 213, U. S. Geol. Survey, pp 306-321, and according to Arnold and Anderson, Bull 357, U. S. Geol. Survey, pp 70-71) may be mentioned. In 1895 Noettling, of the Geological Survey of India, established the fact that the oil fields of the Irawadi, in Burma, famous for over a century, correspond with the structural theory, and presumably belong in this sub-class. The oil and gas in those fields are directly related in their accumulation to anticlines and domes in the Miocene sandstone.

The rocks in the fields comprised in sub-class 2 are folded into alternating anticlines and synclines, bounded by moderate dips, seldom more than 30 degrees from the horizontal. This is the sub-class to which White's and Orton's anticlinal theory, as originally understood, applies strictly. The gas occurs in the upper part of the individual sands or "pay streaks," the oil occurs somewhere below the gas, while salt water, if it is present, fills in the remaining space in the sand (where the latter

is uniformly porous), or occurs in the separate "pays" (where the sand as a whole has not a high degree of porosity), all these deposits being controlled pre-eminently by the force of gravity. Where oil or salt water occurs higher in the sand than gas, it is presumably due to sharp changes in the dip, or to a multiple nature of the "pay streaks."

3 *Where Monoclinal Dips exist with change in Rate of Dip.*

In this sub-class the rocks dip in one general direction throughout, although the dip may vary in steepness. (See Fig. 3). The majority of the oil and gas pools in southeastern Ohio belong in this division. Definite anticlines are not so common in Ohio as in Pennsylvania and West Virginia, as the prevailing dip of the formations is in one general direction (towards the southeast). However, the application of the structural theory, properly understood, is almost as certain of profitable results as it is in Pennsylvania, because the dip is not uniform, but varies from flat to over 5 degrees from the horizontal. Occasionally rounded or somewhat elongated semi-anticlines of sub-class 2 are found.

Oil and gas can be predicted in sub-class 3 through recognition of the principle that any change in the rate of dip is to be considered as a possible place of accumulation; and such a place of accumulation once discovered, the pool can be easily extended (within structural limits) by following lines of horizontality in the sand. While these lines in Ohio or in Pennsylvania more frequently run northeast and southwest, they also take all other directions, according to locality.

To this sub-class may also belong, in part, the Florence field in Colorado, where the oil exists in beds (according to N. M. Fenneman, Bull. 260, U. S. Geol. Survey, page 437) occupying a portion of a structural slope where the sands locally are rather flat for a few miles; being a sort of terrace with dip of less than 5 degrees, while on both sides the dips frequently reach 20 degrees. In this field the sands hold little water.

4 *Terrace Structures*

These are an exaggerated form of the flattenings of dip included in sub-class 3. As a rule the gas is found on the outside of

the terrace and oil on the inside, though this is not the infallible rule. The change in the rate of dip, forming a local interruption, seems to be the essential factor.

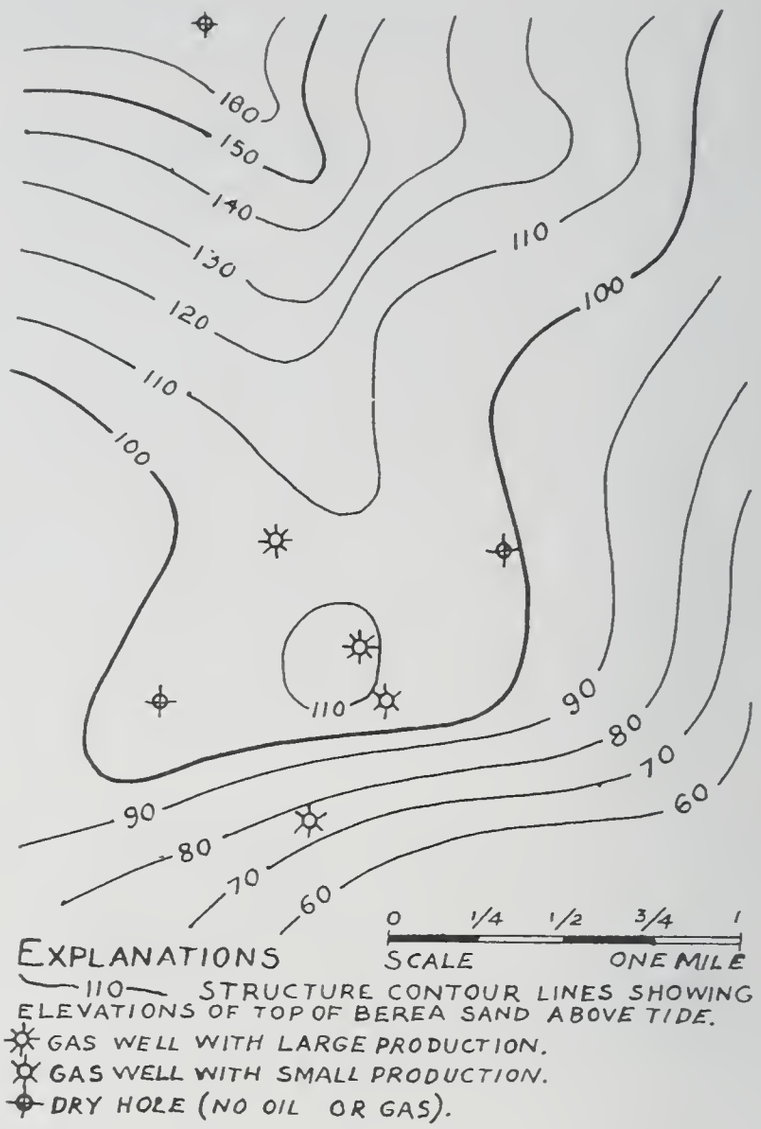

Fig. 5. Structure contour map showing occurrence of gas (according to Class *A4*) in the Berea sand, in a small area in southeastern Ohio.

The effect of terrace structure was first explained and illustrated by Edward Orton in 1886 (Science, Vol. 7, page 563). The terraces described by him were in the Trenton limestone fields of northwestern Ohio. In the Findlay field the oil and gas were found in two terraces, separated by a monoclinal structure. The upper terrace yielded dry gas and the lower terrace, oil and water.

Orton gives the name "*arrested anticlines*" to structural terraces, and cites the Macksburg field of southern Ohio as an example (Geology of Ohio, Vol. 6, page 94). The terrace structure

of the Macksburg field was first recognized by Newhall in 1888 (Geology of Ohio, Vol. 6, Chapter 6).

During the past decade hundreds of similar terrace structures have been discovered throughout southeastern Ohio and to some extent in adjacent states, and most of them are available for oil and gas development. Generally, though not always, the structure can be determined from the geology of the surface, without the need of borings until one is ready to make his test. A good example of terrace structure and the relation of gas to it, is shown in Fig. 5.

E. Broad Geanticlinal Folds

This is an extreme type of sub-class 1. By a geanticline is meant an anticline which is extremely long and broad, and constituates more than a local feature. It extends over thousands or tens of thousands of square miles. One of the best examples of a geanticline in this country is the Cincinnati anticline, which crosses western Ohio and eastern Indiana from the Great Lakes southward into Kentucky, raising the rocks thousands of feet higher than they are in eastern Ohio and western Indiana. The fold causes a complete separation between the eastern and central coal fields; and where the formations are highest immense reservoirs of oil and gas have been developed and exhausted, the oil and gas being contained in the Trenton limestone. Owing to the broad areas under which oil and gas are found in the Cincinnati geanticline the chances of success in drilling were much better than in other fields. The decline of the Trenton limestone fields was due largely to wastefulness of the gas before people understood that all fields are subject to exhaustion. Some of the pools in the Clinton sand are situated along the eastern flank of the Cincinnati anticline, but these pools belong under sub-classes 3 and 4.

Class *B*. domes, or quaquaversal structures. Certain types of anticlines developed as well-marked domes, might be classed here; but since these are included in sub-classes 1 and 2 of Class *A* the domes here considered will be limited to those which are not part of any well developed anticlines, and are thus susceptible of a different classification. The conspicuous examples of

this occurrence are in the fields of the Coastal Plain in Texas and Louisiana, described by Hayes, Kennedy, Fenneman, Harris and others, some of the best known instances being Spindletop, Sour Lake and Batson. The domes are not the so-called "gas mounds" two or three feet in height and a few rods across, which are so abundant in the Gulf Coastal Plain, and which, notwithstanding their designation, have no relation to deposits of gas and oil. The mounds in which gas and oil exist may not show as such at all on the surface (any more than an anticline

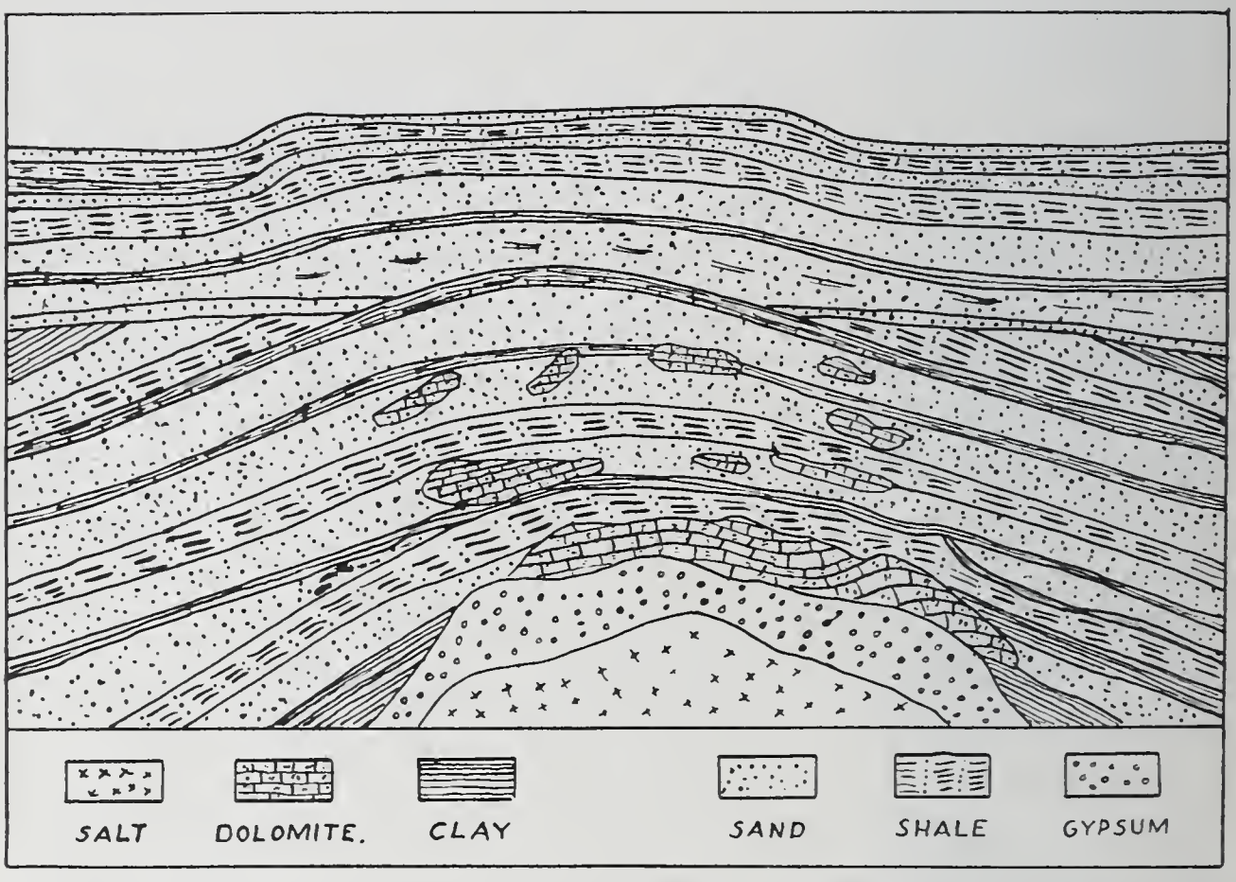

Fig. 6. Section showing general type of a saline, or mound, in which oil and gas occur (according to Class *B*) in the Gulf Coastal Plain of Texas and Louisiana (modified from Harris).

necessarily shows in the surface configuration of Pennsylvania and West Virginia). Sometimes they appear however, as circular hillocks covering several hundred to several thousand acres and rising 25 to 100 feet above the surrounding plain. They are frequently known as "salines" because they contain deposits of rock salt.

Underneath the surface the whole body of strata has a domelike shape, containing, in addition to the ordinary forma-

tions, limestone, salt, gypsum and sulphur, all of which have been pressed upwards in approximately circular outline by some great force acting from below. Geologists believe this force to have been crystallization of the gypsum, salt and sulphur deposits from aqueous solutions. (See Fig. 6). The mounds in which oil occurs lie at the intersection of lines (perhaps fault lines) having different directions and which can be worked out by studying conditions over a broad area of surrounding country.

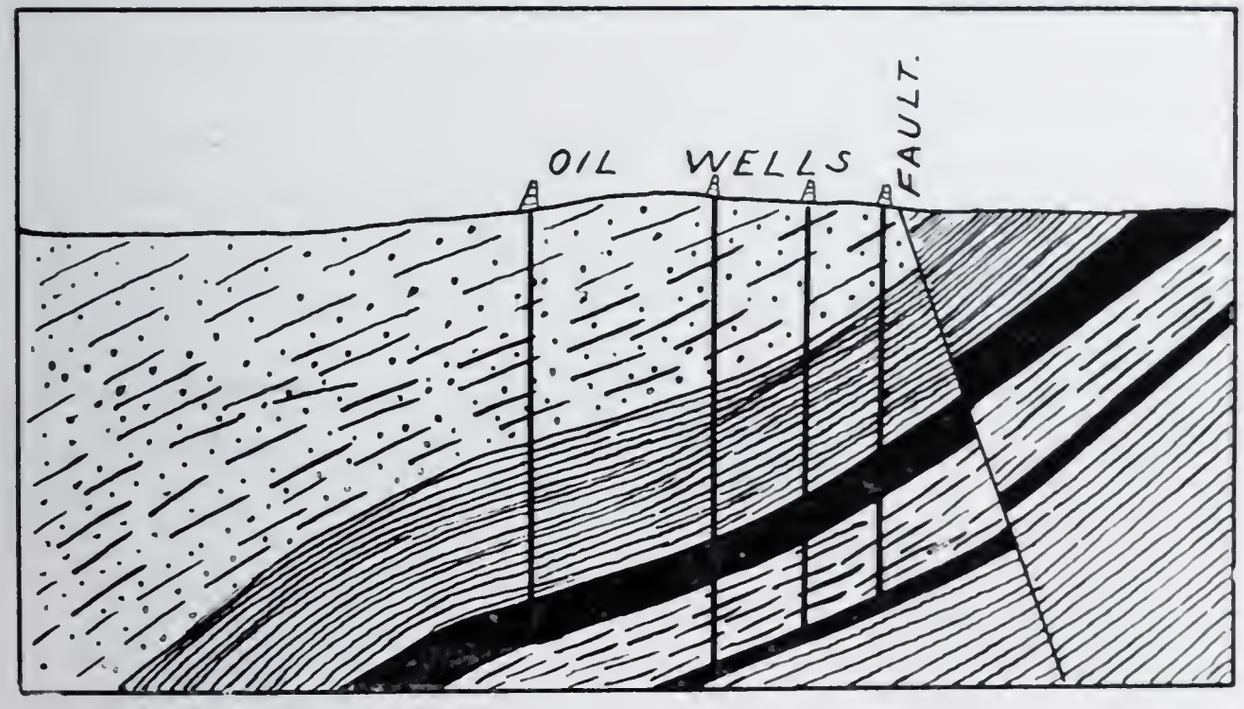

Fig. 7. Section showing occurrence of oil pools sealed in by a fault plane (according to Class *C*). (After Arnold, in certain California fields. The black formations are the oil sands.)

Class *C*. Along sealed faults. The known examples of this class consist of some of the pools in the Los Angeles field and some of those in the Lompoc field in California described by Arnold in Bulletins 309 and 322 of the U. S. Geological Survey, 1907. (See Fig. 7). In these cases the highly inclined oil sands are cut off abruptly below ground by a fault, thus sealing the oil and gas in the sands and preventing their escape to the surface. Most of the producing oil wells of the M'Kittrick district in California are situated in a zone less than a quarter of a mile wide and in places less than 200 feet wide along an overthrust fault line (Geo. H. Eldridge, Bull. 213, U. S. Geol. Survey, pages 208-209). Some of the other oil fields in California

probably belong in this class. To illustrate the probability that such cases are more frequent than known, it is observed that oil springs frequently occur along fault lines. Some of these cases occur in British Columbia and others in Gaspe, Quebec.

CLASS *D*. OIL AND GAS SEALED IN BY ASPHALTIC DEPOSITS. This occurrence may perhaps be exemplified by the Pitch Lake of Trinidad, where small quantities of oil and gas are said to occur, but this example cannot be stated with certainty. Some of the oil found near the vein of grahamite at Ritchie Mines, West Virginia, may belong in this class, although these deposits are also dependent in their original accumulation upon anticlinal and synclinal structure, as in Class *A*.

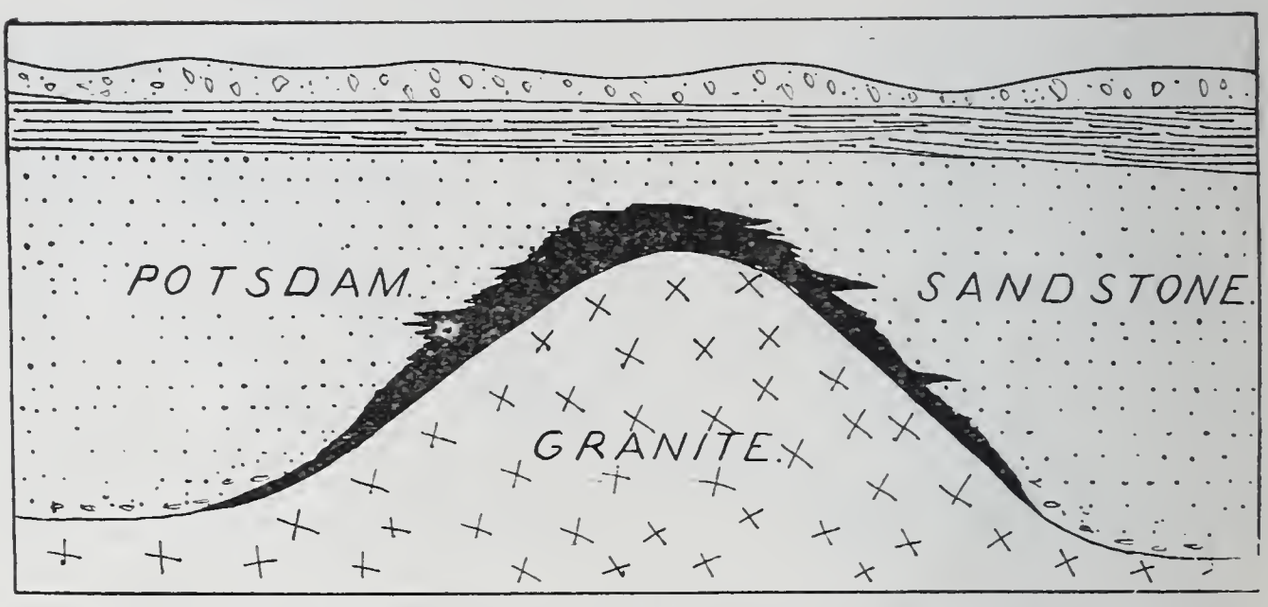

Fig. 8. Section showing occurrence of gas (according to Class *E*) in the Province of Quebec.

CLASS *E*. AT THE CONTACT OF SEDIMENTARY AND CRYSTALLINE ROCKS. The principal examples of this class are in the Province of Quebec and northern Ontario, and are not yet well known. It is probable that gas occurs at some places in northern New York State in this way. The writer has not at hand any record of oil occurring in such a position, but gas occurs in commercial quantities. It is held in the zone of the lower Potsdam sandstone which is of arkose nature (made up largely of granite fragments) and rests directly upon the granite. The deposits seem to occur on prominent knobs of the granite under the sandstone capping, something as in Fig. 8.

CLASS *F*. JOINT CRACKS. This class has been added at the suggestion of Mr. M. R. Campbell. It is represented by a part at least, of the Florence field in Colorado and probably by some New York fields. In this class the oil occurs in joint cracks, in shales and other impervious rocks.

OTHER FACTORS CONSIDERED BY A GEOLOGIST. Besides structure it is important for a geologist to study the difference in specific gravity of the oil in different parts of the field and in different sands, and the thinning of the sands in certain directions.

The changes in porosity of a sand, are, of course, very important as governing its capacity for holding oil in particular places and directions. In a loose sand a less inclination of the strata will suffice to form an accumulation than in a close grained sand. Local changes in porosity cannot, as a rule, be predicted, but the general character of a productive sand holds throughout a particular field. In the case of the Trenton limestone, the Clinton sand and the Big Lime of Ohio and West Virginia, the local chemical composition of the strata is important.

Another factor of importance is the degree of saturation of a sand, although as has been explained, the position of the water line is not so important as some persons have supposed. In the Berea grit, for instance, some pools have been found, and are still being found, where the oil lies below the water line in neighboring portions of the sand. Many of the recent oil developments have taught lessons which it took operators and geologists years to learn, but now that the lessons have been learned, they are productive of good results.

The fields in the deeper sands frequently do not correspond structurally with those in the shallow sands, and this is one reason why they are not discovered more rapidly. As a rule, the shallow sands are productive at or near the crests of anticlines, and are frequently confined to domes in these crests, while the deeper sands may be, and frequently are, dry on the crests, and productive on the flanks of the anticlines where they dip moderately steeply towards the adjacent synclines. And since the size of the pools is approximately inversely propor-

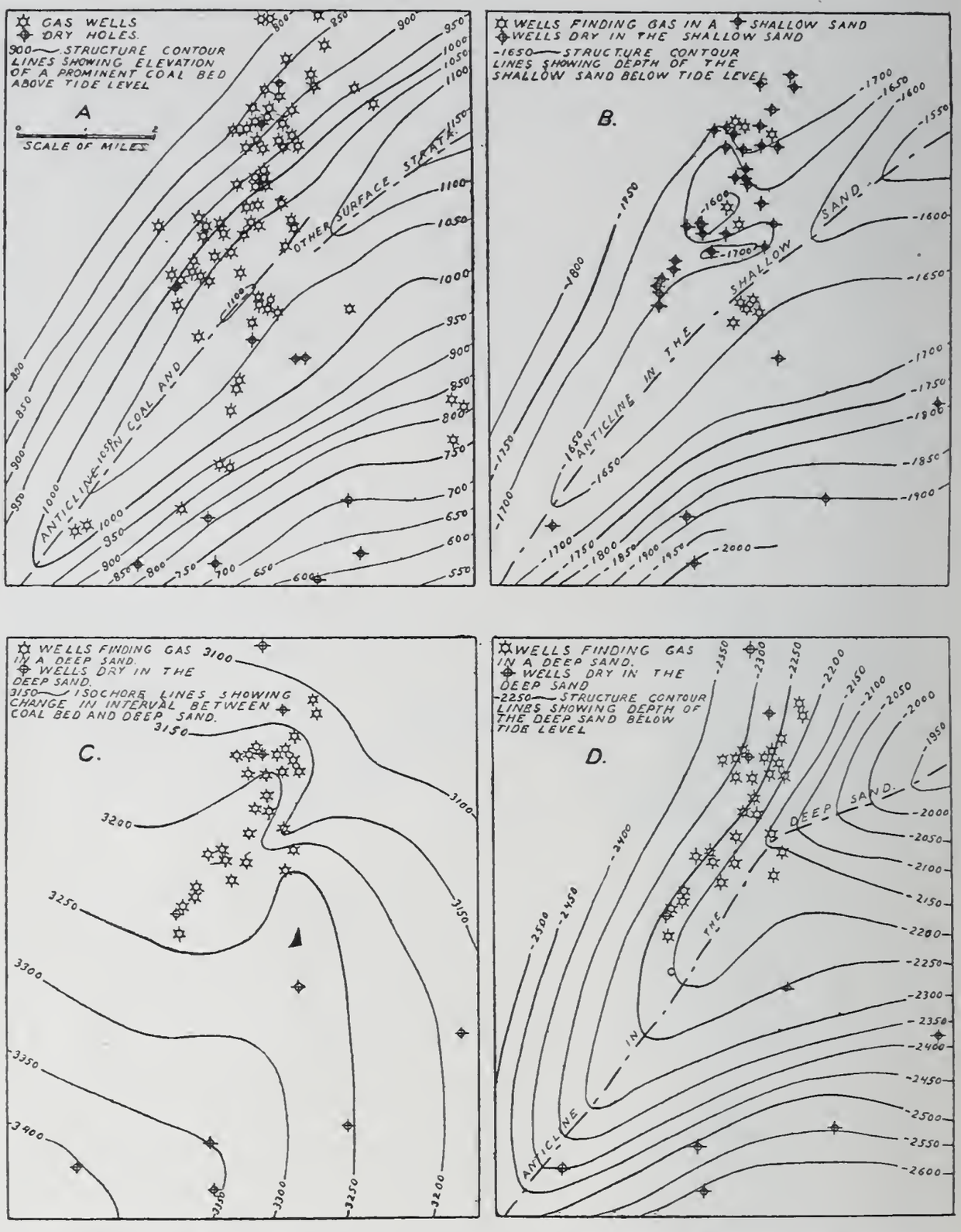
GAS WELLS
DRY HOLES.
900— STRUCTURE CONTOUR LINES SHOWING ELEVATION OF A PROMINENT COAL BED ABOVE TIDE LEVEL
A
SCALE OF MILES
OTHER SURFACE STRATA
ANTICLINE IN COAL AND
WELLS FINDING GAS IN A SHALLOW SAND
WELLS DRY IN THE SHALLOW SAND
-1650— STRUCTURE CONTOUR LINES SHOWING DEPTH OF THE SHALLOW SAND BELOW TIDE LEVEL
B.
SHALLOW SAND
ANTICLINE IN THE
WELLS FINDING GAS IN A DEEP SAND.
WELLS DRY IN THE DEEP SAND.
3150— ISOCHORE LINES SHOWING CHANGE IN INTERVAL BETWEEN COAL BED AND DEEP SAND.
C.
WELLS FINDING GAS IN A DEEP SAND.
WELLS DRY IN THE DEEP SAND
-2250— STRUCTURE CONTOUR LINES SHOWING DEPTH OF THE DEEP SAND BELOW TIDE LEVEL
D.
DEEP SAND
ANTICLINE IN THE

Fig. 9. Illustration of gas field in Pennsylvania belonging to subdivisions of Class *A;* (showing how the agreement between geological structure and position of the gas field may not be evident from the surface structure; but shows plainly when the non-parallelism and the structure of the individual sands has been determined).

A shows "lay" and dip of surface strata, with positions of all wells.

B shows "lay" and dip of a shallow sand, with position of wells drilled to it.

D shows "lay" and dip of a deep sand, with position of wells drilled to it.

C is a convergence map used in calculating the "lay" of the deep sand for Fig. *9D*.

Note the agreement of productivity with structure in *B* and *D*.

tional to the steepness to the dips, these deep sand pools generally take the longest to be discovered by the drill.

The possibility of maintaining the supply of petroleum and natural gas is due to two factors: First, to the frequent discovery of new oil fields, and Second, to the discovery of new sands in old fields. Pennsylvania, West Virginia and southeastern Ohio have the advantage, not enjoyed by all fields, of containing scores of sandstone and limestone formations suitable for holding reservoirs of oil and gas. Judging from the history of the fields during the past few years, it seems reasonably sure that the discovery of new fields in this part of the country will continue for many years to come; although the productive territory has probably reached nearly its maximum total area. In certain other countries these industries are still in their infancy, and in some countries future development is destined to be very important, and opens good opportunity for American capital. Such is true in some parts of South America, certain portions of which have never been seen by an engineer, and in some of which the conditions are favorable for the existence of oil and gas. It seems probable that the fundamental lessons have been learned, and that the geological and engineering sciences will in future play a much more important part in the development of new fields than they have in the past.

DISCUSSION

Mr. H. W. Fisher: I presume the different sands referred to are really sandstone formations. Are they porous enough to contain the oil, or is it located in cavities? How long will the supply of oil last at the present rate of consumption?

The Author: I have used the driller terms for convenience. The *sands* referred to by well drillers are in most cases sandstones. In some fields they are really unconsolidated sands, but in most fields they are similar to our Pennsylvania sandstones which outcrop at the surface, and are very hard. A sand may be a continuous stratum for miles, or it may run horizontally into shale in places, as do the Mahoning, Saltsburg and other sandstones which outcrop along our rivers. For instance, the cliff of massive sandstone which is so conspicuous opposite the town of Saltsburg, when followed laterally from hill to hill,

changes into shale within a very few miles The deeply buried sandstones (or sands) do the same way.

The lateral changes in the character of the sands are important as affecting the porosity, and explain some of the cases in which gas is found only part way up the slope of an anticline or monocline. The gas has in such cases risen as far as possible, until barred by a too impervious part of the sand. A similar statement will apply to oil, where it is not found as close to the bottom of the syncline as would be the case if the sand were more uniformly porous.

The question of the duration of the fields is a difficult one. Of course all fields are subject to exhaustion sooner or later. The exhaustion of the Trenton limestone fields in northern Ohio, and Indiana, and even some of our best Pennsylvania fields, shows that individual fields are comparatively short lived, as regards their usage. While they may have taken from a million to ten million years to accumulate geologically, the oil has been exhausted by pumping, so that in most cases they only last a very few years. Some wells are productive in Pennsylvania and West Virginia which have been pumped nearly every day for 40 years, but other fields, recently discovered, have been practically exhausted in a few months.

The oil supply of the world must be maintained, not from individual drill wells or pools, but by the discovery of new wells, new pools, and new oil fields. There are many countries where oil has never been developed at all, and where it has not even been discovered, where conditions are such that it will undoubtedly be located sometime, either by geological exploration or by drilling. For instance there are only about three countries in South America where oil has been developed; while many of the other countries undoubtedly contain oil, but it has not yet been discovered. In many places the formation is suitable, but the unfavorable conditions of the country have caused investors and prospectors to go elsewhere. Personally, I believe there is a great future for South America, and also for Africa. There is also undoubtedly oil in some of the more civilized parts of the world where it has not yet been drilled for. That is true even in certain parts of our own country.

Another factor in the maintenance of the supply is by the

discovery of new sands in the old fields by drilling deeper. In Pennsylvania and West Virginia, as fast as oil and gas are exhausted in the shallow sands, they seem to be discovered in deeper sands. The latter are frequently not so productive as the shallow sands, but they contain large supplies. The fact that in Canada some of the recent wells have found gas directly on top of the granite, in one of the oldest sandstones, geologically, is evidence that gas, and possibly oil, exists in even some of the oldest formations.

There are so many untapped sedimentary oil fields, and so many untapped sands in existing fields, that we are sure to have gas and oil for many years to come. They should be developed wisely and used wisely, however, for they *are not inexhaustible.* Even in Pennsylvania, I believe fields of limited extent will continue to be found for several years. Pittsburgh will have natural gas for domestic use for 20 or more years; but the time will soon come when it cannot be used profitably for manufacturing purposes. With the present depth of wells, the profit in the gas business is not great and with the average depth of wells increasing year by year, a cheaper method of drilling must be discovered if we wish to produce gas from deeper sands.

Mr. R. B. Woodworth: This has been an extremely interesting paper to me. The members of the society will doubtless recall that I touched upon this matter of the application of geology to deep well drilling in a paper read before the Structural Section on the Steel Oil Derrick, printed in the Proceedings for June, 1909, No. 5 of Vol. 25. Mr. Clapp, however, has covered the subject much more fully than I was able to do and with much more accurate information.

The application of geology to the drilling for oil and gas, or in fact to any deep well drilling, is, in my judgment, a subject which has been forced upon us more or less as a result of the advancement of the application of scientific methods to engineering in all directions. There was a time when it was possible for men to claim to know all sciences. The researches of Aristotle, for example, covered all that was known in his day and generation touching the material universe. Roger Bacon in the 13th century claimed that all knowledge was his province, and his investigations covered the widest range of scientific, linguistic

and theological research. There came a time, however, in the course of affairs when men became specialists; when they devoted their attention to one department of knowledge which they prosecuted to the exclusion of all else. The result of the intense specialism of our time is to narrow a man's outlook and to limit his usefulness.

The application of geology in the drilling of deep wells is, in my judgment, a return to what is, beyond question, the duty of the civil engineer and in fact of all classes of engineers; namely, the application of all kinds of knowledge to his own profession, making them subsidiary, if you please, but still necessary to the main pursuit of science. The trained engineer should be distinguished by a breadth of scientific vision. He should be able to use as his servants scientific research of every kind so far as it contributes to the advancement of his profession. Architecture used to be the specialty of an architect. The steel frame building has made the architect an engineer as well. The progress of knowledge has made the mining engineer a geologist, a surveyor, a machinist, an electrician and several other things besides if he is fully competent to oversee and to direct the various applications of science as they are met with today in large mines with their extensive underground operations, their operating machinery, lighting, etc.

It was said by men of old time that so many languages as a man knew, so many times was he a man. It is true today that the more arts and sciences an engineer can bring to bear on the problems which arise in his profession, the more of an engineer he is and the more perfectly does he come up to the measure of a true enginer, who has been described to be the "man who does things." The structural engineer today needs to know not only the theory of materials, but the contributions which have been made by metallurgical chemistry and by physical experiment in order to utilize them in his profession, and the fact that a paper on the application of geology to the very practical problems of drilling oil and gas wells should be presented to this Society is a proof not only of the gradual advancement of science itself, but of the recognition of the fact that the proper development of our natural resources wisely and economically is today developing a type of engineer distinguished by depth

of training and by breadth of vision. The age of specialists has not of course passed but the position occupied by the engineering profession today is in advance of that which it occupied twenty years ago, largely by reason of the fact that it has been wide enough awake to utilize for its own ends the contributions of all kinds of sciences, and the engineer will continue to maintain a prominent position in the affairs of the world in the years to come only in so far as he will fully avail himself of the researches of all kinds of sciences which may have any bearing whatever on his particular line of practical work.

There are two advantages which the study of geology gives to the mining engineer who is prosecuting the search for oil and gas. One, that it does materially assist him in the selection of those locations in which there is a probability that his efforts in the search will be successful. As Mr. Clapp has said, there are two men who have been most influential in this direction: Dr. Edward Orton, State Geologist of Ohio, whose acute mind and facile pen have done so much to enforce the geological claims of the anticlinal theory on which the application of geology to deep well drilling has been so largely based, and Dr. I. C. White, State Geologist of West Virginia, who, more than any other man, has contributed to the practical application of geological theory in the location of oil and gas wells. Guided by geological theory Dr. White pointed out and located all the great oil pools of West Virginia long before the drill finally demonstrated the correctness of his conclusions. On the Mannington—Mt. Morris belt, for example, a derrick was built to bore for oil on one of his locations more than five years before the drill finally proved that his location was immediately over one of the richest pools in the country and before the drill had shown that there was any oil in that part of West Virginia. The second advantage in the application of geology to deep well drilling consists in the fact that while it is beyond the powers of geological science to foretell whether any particular boring will yield either oil or gas in commercial quantities, but only indicates probable localities, it does limit the search for oil or gas to regions having a peculiar geological structure where experience has shown that the occurrence of oil or gas is possible, and thereby eliminates from consideration territory where there is no likelihood

at all of oil or gas ever being discovered. As an instance of this sort might be cited a locality in West Virginia where hundreds of acres of land have been optioned for drilling purposes but where, so far as a study of geology indicates, there is absolutely no possibility of there being either oil or gas and certainly no inducement to anyone to invest any money in the enterprise on the probability of receiving an adequate reward for his labor. Wildcat operations will no doubt continue, but with such scientific methods have nothing to do.

The data used by geologists in the location of oil and gas wells are arrived at by different methods, chiefly from convergente sheets based on the records of wells already driven. There is one point, however, in this connection to which attention might be clearly drawn and which, so far as the speaker is aware, has not received adequate consideration. The geologists plot the records of the different wells to locate different sands. Now, there is no oil or gas well which is drilled perfectly straight and true into the ground, and it occurs to the speaker that some of the divergence which may be noted in geological sections is due to the overlooking of this point. Those who are familiar with diamond drilling know that it is almost absolutely impossible to drill a straight hole, because as the drill goes down it encounters strata of different density, some of which may be very hard and some of which may be soft. The tendency of the drill in such cases is to follow along the line of least resistance and the consequence is that as you go down the hole may vary more or less from a vertical position, so that when you arrive at the bottom it may be going in a diagonal or even a horizontal line instead of on a perpendicular. There have been methods devised by which the course of the drill may be surveyed and by which the exact location of the drill hole at any point may be plotted, and such methods are absolutely necessary where drill holes are put down along property lines.

The holes put down for oil and gas in all probability are no straighter than those put down with a diamond drill, in spite of the much larger size of the hole, and an illustration of this may be found in the fact that very often the casing in a well pulls extremely hard and pressure has to be exerted to get it out. In one instance the top section of a steel oil derrick was

pulled over bodily by the efforts of the men to remove the casing, and, beyond question, a great deal of the difficulty was due to the lack of verticality in the hole. It stands to reason that if the holes were drilled perfectly straight, there would be no special difficulty in the removal of the casing, but where the strata are somewhat inclined the drill will naturally follow along the line of least resistance, with the result that the hole gets out of plumb and the casing pulls hard. This point should be considered in the correlation of the records of deep well drilling and makes plain part of the lack of uniformity which is to be seen in geological sections extending over a large area of territory.

Mr. H. W. Fisher: I have been very much interested during the last year in the different kinds of oils and especially in the residuums of oils. The residuums of our Pennsylvania oils are quite different in viscosity from Texas oils. The residuum of Texas oil has a very long viscosity slope. The melting point may be 200 and it may not be brittle at freezing, whereas some of the Pennsylvania oil residuums become brittle much more rapidly at low temperatures. There are some very interesting characteristics which can be used to advantage in the arts after one has studied them very carefully.

I would like to ask Mr. Clapp if there are any theories as to the difference between Texas and Pennsylvania and other oils, and whether this difference was brought about by the original composition of the oil, or by the pressure under which it exists, or by other ingredients that came in contact with the oil? There are very curious differences in these oils. In some of them the viscosity varies as the pressure applied to force the compound out, and in other compounds it varies as the fourth power. I gave a talk before a study club a short time ago and to illustrate this point I had two or three boxes with compound in them. The compound in one case was very viscous and in another case not so viscous, and to illustrate viscosity I laid some machine screws on these compounds. In one compound during 24 hours the screw sunk until the top was just level with the surface, and in another it had hardly dented the compound at all, yet the latter was the softest. That shows extreme difference in viscosity. If you are trying to saturate a dozen or more thick-

nesses of paper with a compound of high viscosity, you will probably find that the compound will not penetrate all the papers, whereas with compounds having a less viscosity slope, and which therefore become fluid much more rapidly, thorough saturation may easily be obtained. These points are very interesting and essential in electrical engineering. It would be interesting to know something more about the structure of oils and residuums.

THE AUTHOR: The question of the cause of the different viscosities of oils in different fields and in different formations, is a matter I have not investigated, and am hardly prepared to discuss. Great differences in chemical and physical properties exist and are recognized, but I do not know that geology has as yet satisfactorily explained them.

MR. W. F. HALL: Are gas and oil still in process of formation? I have some slight knowledge of a well located near Butler, which for a long time was non-productive, later, the oil or gas accumulated and I wondered if it came from another place or was being formed by nature.

THE AUTHOR: Oil will sometimes return, in a measure, to a well that has been abandoned, owing to the fact that the small quantities of disseminated oil remaining in the sand will slowly gather themselves again into the position of the oil before the pool was developed; that is, into harmony with the geologic conditions. This takes place, as originally, mainly through the influence of gravitation. But oil does not continue to be formed by nature, by any means. That is, after an interval of some years, no more oil exists in the sand, but the particular favorable plan for the accumulation may, in certain cases, contain an increased amount of oil. If the well Mr. Hall describes was situated on the side of the pool where the productive sand was lowest, the oil in the abandoned well probably simply settled into place from the higher parts of the stratum, in the same way that the original pool accumulated. When an oil well is reported as "exhausted," that does not mean that all the oil has been pumped out, because some oil always remain which cannot be extracted with profit; and in a large pool a good deal of oil may settle into the lower part of the stratum after the field is exhausted.

Mr. F. B. Martin: I have seen cases where there is a cliff 80 or 100 feet high, down at Leetsdale for instance, with a well on top of the cliff and another at the base. Would you have to drill to the same depth in each case?

The Author: The well on top of the cliff would have to go just 80 or 100 feet deeper from the surface than the well at the base, plus or minus whatever amount (generally only a few feet) the oil sand might dip or rise in the horizontal distance between the two wells.

Mr. F. Z. Schellenberg: We do not have in Pennsylvania a requirement they have in Ohio, that the land owner must record the position of the borings on his land. As years go by and the surface indications are obliterated there is danger in mines of striking those holes and having serious accidents therefrom. Of course the driller is a man who is here today and away tomorrow, and it is the land owner who should locate the position of the well and put it on record in the Recorder's office in the county; that law we ought to have here. There have been accidents in mines from running into holes that were drilled even for testing for coal only, and we know of wells that have been tapped and oil and gas got into the mine. And certainly it is worse when there are unknown wells to be encountered. They will be a continuous danger.

Referring to hydrocarbons in older rock, I was in a silver mine in Western Ontario where they had gas and got rid of it by the oldest way, that is they fired it by thrusting a candle into a small pocket of it back along the roof occasionally. It was of course in a dike through black carbonaceous slate. They have also what appears something like anthracite. In what I take to be the Silurian they have these strings of anthracite, (containing 10 percent of volatile matter) as premonitions of the carboniferous formation. As to asphalt, sulphur has perhaps changed the oil into the asphaltic condition. We understand the effect of sulphur artificially on the vegetable carbons at least is to harden them; a drying effect it is called.

Mr. P. S. Whitman: I would like to ask Mr. Clapp to explain the organic theory in geology.

THE AUTHOR: The organic theory of the origin of oil and gas is that the various sedimentary strata were originally deposited on ancient sea bottoms. Animal and plant life existed at that time and hence large amounts of organic matter must have been buried; persons who believe in the organic theory, believe that the bituminous substance, which resulted from the decomposition of the animal and vegetable matter were changed by natural processes into oil and gas.

There is another class of people who believe in the *inorganic* theory. Their view is that gas and oil are greatest in the interior of the earth. They account for this in various ways. Some think the substances have always been there and simply have worked themselves out to strata near the surface. Others claim that water, working itself down through the earth crust, charged with various organic acids has reacted on carbides of iron and other substances which are supposed to exist in the interior of the earth, and in some way have evolved gas and oil. There are variations of these theories, and theories between them. Some geologists believe one, some believe the other, while some believe both theories are true in part.

To my mind there is just one argument that would seem to perhaps favor the inorganic theory. I have always believed in the organic theory, because the weight of evidence has seemed to be on that side; but recently I have learned a good deal of the deeper lying deposits; particularly of the deposits of gas lying directly on top of ancient crystalline rocks. This occurrence would seem to offer a possible argument in favor of gas, at least, originating through the inorganic theory by chemical action. In fact, if we but consider the logic of the matter, is it not very possible that such a method of formation would take place? Everything we have, on and in the earth, whether at present organic, or inorganic, was once a part of the original inorganic mass of the earth, or of its atmosphere (or of inorganic planitessimals, as some scientists claim); and why should not chemical action be capable of originating any earthly substance without the necessity of going through complex organic processes? This possibility would seem to be worth pondering, and may help in making the inorganic theory seem plausible.

THE SELECTION OF A BOILER FEED WATER

By J. C. William Greth *

Engineers and chemists are frequently confronted with the question, Will water of a certain analysis prove to be a boiler feed supply which will neither scale nor corrode?

With a water containing considerable amounts of scale forming impurities or containing any corrosive acid, it is evident that scale, or corrosion, or both will result. In waters having small amounts of impurities the solution of the problem is not easy, because so many different substances make up these impurities, each affecting the other to a greater or less extent, depending on the relative amounts of the substances present. The type of boiler and the conditions under which it operates also enter into the problem.

It is not always safe to base an opinion upon the number of grains per gallon of impurities in a feed water, for in some waters as much as eight grains may be present without any scale resulting, except possibly, in the heater and pipe lines, while, on the other hand, many waters with only three or four grains per gallon cause hard scale and in many instances corrosion.

In the generation of steam the heat alone causes the precipitation of some of the impurities in the feed water; it also drives off certain gases and volatile substances and brings about the decomposition of some of the soluble salts. The heat, together with the concentration resulting from evaporation, also produces reactions between the soluble substances, causing the precipitation of scale-forming substances and the liberation of corrosive acids.

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* Assistant Engineer, Pittsburgh & Lake Erie Railroad Co., Pittsburgh.

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*Manager, Water Purifying Department, Wm. B. Scaife & Sons Co., Pittsburgh, Pa.

These changes in the soluble substances when generating steam in a boiler are all in accordance with facts well known to the chemist, and must be taken into consideration when a feed water supply is to be selected or provided.

The suspended impurities, while a factor in considering the availability of a water for boiler feed, are of minor importance, and the obvious remedy is their removal by sedimentation and filtration.

The soluble impurities carried by a water may be divided into two classes, organic and inorganic. The organic matter is usually small in amount and seldom plays much part in scaling or corroding boilers. The inorganic impurities, however, are the usual cause of all boiler troubles. The most common soluble inorganic impurities are lime, magnesia, iron and sodium in combination with carbonic, sulphuric, hydrochloric and in some cases nitric acid. There is also found a small amount of silica, oxides of iron and alumina, some free carbonic acid and in some waters free sulphuric acid, in others hydrogen sulphide. Other substances will be found, but those given above represent the usual impurities in water with which the engineer or chemist is concerned, in deciding whether boilers can be operated at maximum efficiency with low maintenance expenses.

These soluble mineral substances may be divided into two classes, non-scale forming and scale forming.

The non-scale forming substances consist of the sodium salts, which are soluble under all conditions in the boiler and are not objectionable in feed water unless present in very large quantities, for they are non-scaling and non-corroding. But the sodium salts are often charged with being the cause of priming and foaming. It is the common belief among engineers that the sodium salts are the direct cause of priming and foaming in boilers, and of these salts sodium carbonate (soda ash) is the one most feared.

This fear of the engineers is no doubt due to the difficulties often encountered when using a natural water containing sodium bicarbonate, which often causes violent foaming, and also to the misuse of soda ash in heaters and boilers, where its action is entirely different from the proper use of it in soft-

ening and purifying water before going to heaters or boilers. When used in this manner in correct amounts it is not present in the treated water as sodium carbonate (soda ash), but as sodium sulphate, chloride or nitrate as a result of its complete reaction with the corresponding acid radicals of the raw water.

The priming and foaming in boilers sometimes occurring immediately after beginning the use of a water softened and purified with lime and soda ash or caustic soda has led to the belief that the soda treatment was the sole cause of it; but close observation and many analyses of concentrated boiler waters now warrant the belief that the cause is to be found among the following factors: The nature of the impurities in old scale, or those introduced into the feed water by the exhaust steam; the design of boiler; the water space; the steam space; the arrangement and size of steam piping; irregularity of load; improper firing and feeding.

As a matter of fact it is not the mere presence of the sodium salts that causes the foaming, but it is undoubtedly due to the presence of other substances, which, together with the sodium salts, bring about a condition in the concentrated water that induces foaming.

That foaming is not directly chargeable to the sodium salts is almost conclusively proven by the fact that with a properly treated and purified water in which the sodium sulphate, chloride, nitrate and carbonate total 100 grains per gallon, with the sludge forming substances less than 3 grains per gallon and with no scale forming substances present, no foaming results if the boilers are clean. But if such a water is fed into boilers badly scaled, the scale begins to disintegrate and during the time the old scale is coming off, foaming often occurs. Experience has shown that priming and foaming cease as soon as the boiler becomes clean, if the boiler is regularly blown off and occasionally emptied and refilled with fresh water.

As an illustration, the analysis of the concentrated boiler water, after a two weeks' run with a softened and purified water containing 116 grains of sodium salts, showed 1936 grains per gallon of sodium salts. This water has been in successful use for a number of years under severe conditions of

irregular and sudden, heavy loads. On the other hand, a natural water containing a total of 5.26 grains of solids, of which the sodium salts amount to only 0.12 grain, produced a considerable quantity of hard scale. To overcome the scaling a boiler compound (practically all soda ash, colored with a little tannic acid) was used. After four days' operation, an analysis of a sample of water from the blow-off when the boilers were foaming and priming violently showed a total of 119.54 grains of solids, of which 78.00 grains were sodium salts, and there were also present 122 grains of suspended impurities. When the boiler compound was discontinued the foaming ceased. In this case it would seem to be conclusive that it was not the mere presence of the sodium salts introduced in the compound that caused the foaming, but the presence of other substances in the boiler or in the compound. The boilers were shut down at the end of the week and the condition of the scale in the tubes is shown by the illustration Fig. 1.

Fig. 1

Water from either jet, or barometric, condensers and from many natural supplies is contaminated with oil or grease, and all waters heated in open exhaust steam heaters receive with the condensed steam more or less animal or vegetable oil, unless a strictly pure mineral oil is used for lubricating.

The mixture of organic oils with water containing sodium carbonate will produce a soapy emulsion, and undoubtedly many cases of priming or foaming can be attributed to this cause.

Some authorities have gone so far as to state the amount of sodium salts allowable. Others, the limit of concentration that can be carried with safety, and one has developed a formula to determine whether or not a water will cause foaming. Actual experience with all kinds of feed water clearly shows the fallacy of such conclusions.

The sodium salt carrying capacity of a water for successful use for boiler feed is greater in those waters which are clear and remain clear even after concentration, or, in other words, those that are practically free from scale-forming salts, suspended matter and oily matter.

The concentration of the sodium salts can be controlled by proper blowing off. Being able to operate boilers without scale and corrosion more than compensate for any loss of water at boiler temperature that it may be necessary to waste by blowing off to control concentration.

The soluble scale-forming substances are usually divided into two classes, those which cause temporary hardness and those which cause permanent hardness. Temporary hardness is due to the carbonates of lime, magnesia and iron; the precipitation and removal of these begin at temperatures below the boiling point, and is practically completed by continued boiling at atmospheric pressure. Permanent hardness is due to the sulphates, chlorides and nitrates of lime, magnesia and iron, which, as a rule, are not precipitated or removed at temperatures below the boiling point.

Another group of the soluble impurities in water, those which cause corrosion, includes the acids and those substances, which by heat alone, or by heat and concentration, react, liberating corrosive acids.

The amount of impurity which a water contains is not always a criterion of its adaptability as a boiler water, for many waters which contain only small amounts of scale-forming impurity are the cause of much waste and expense. The evaporation of water from the boiler results in a continual concentration of the impurities introduced with the feed water. Nothing but the volatile impurities and pure water, as steam, leave the boiler when the boiler is generating dry steam, which all

boilers are supposed to do. Consequently there is a constant increase in the amount of impurities in the water in the boiler, the results of which are apparent as suspended matter, scale, corrosion and increased density of the boiler water.

The suspended matter may be carried in with the feed, or may be due to substances forced out of solution as a result of either heat or concentration, or both.

Scale formation in the boiler is due to the action of heat, pressure, and concentration on the impurities in solution and suspension in the feed water.

Corrosion of the boiler is due to the introduction of corrosive gases and acids, or their formation from some of the impurities in solution in the feed water, by the reactions resulting from heat, pressure and concentration.

The increased density of the boiler water is due to the concentration of the sodium salts and of the scale-forming salts, to the limit of solubility.

Scale can nearly always be attributed to the lime and magnesia salts in solution in the water. The scale deposited in exhaust steam heaters is almost invariably that of the temporary hardness. Heating the water drives off carbonic acid and converts the bicarbonates of lime and magnesia into the practically insoluble carbonates which are deposited as sludge or scale. Those waters which contain considerable temporary hardness quickly interfere with the efficiency of the heater and necessitate frequent cleaning. The action of heat in precipitating the temporary hardness is not an instantaneous action, and, therefore, the pipe lines from heaters to feed pumps and from pumps to boilers eventually become clogged with scale. The character of the scale in the boiler depends on the acids combined with the lime and magnesia, as well as the rate and pressure at which the boiler is operated.

Scale and corrosion are closely related, because of the number of salts which, as a result of heat and concentration, either decompose or react, liberating acids, and forming solids which are either precipitated directly or after concentration. The precipitated solids form scale and the liberated acids cause corrosion.

It cannot be assumed that because an analysis of a stream shows a water of good quality, that the same will apply to the stream at any point, for, while a stream near its source may show only a small amount of temporary hardness, and not cause trouble from scale or corrosion, at points lower down it may, due to contamination from acid wastes or mine drainage, show mainly permanent hardness and be both scaling and corroding.

To decide on the suitability of a water for boiler feed an accurate analysis of the water is essential. This analysis should be complete and be carefully made by a chemist who makes a specialty of water analyses, and not by one who is unfamiliar with the characteristics of various waters in relation to boiler operation. The analysis of scale is of practically no value in determining the character of the water from which the scale was deposited, on account of the fact that the scale is the precipitation resulting from reactions between some of the substances in solution, as well as by heat and concentration, so that the original character of the impurities in a water are not always apparent in the scale.

The amount of scale-forming impurity in the water does not always indicate the kind or amount of scale formed, but an analysis of the water will show clearly whether or not scale and corrosion will result. Such general statements that waters containing principally the carbonates of lime and magnesia will form a comparatively soft scale, and that the calcium sulphate will form a hard scale, and further, that it will increase the hardness of the carbonate scale, should be made with caution, for there are many instances where a hard scale is formed from waters containing mainly the carbonates of lime and magnesia, and also where the scale is quite soft, in the presence of considerable calcium sulphate.

The nature and amount of scale formed in a boiler depends largely on the rate at which the boiler operates. The type of boiler also has a bearing on the hardness of the scale. The scale in the water tube boiler is generally harder than that formed in the return tubular boiler, or in the old two-flue boiler, from the same water.

It is an easy matter to determine the amount of impurities carried into the boiler with the feed water, but it cannot be definitely stated how this amount will be divided between sludge and scale. Both are objectionable and have no place in the boiler.

Of the various scale-forming impurities in boiler feed water, probably none causes more trouble than calcium sulphate, which seems to be, in nearly all cases, the cement which holds and binds the other precipitated substances, as well as the suspended matter, into scale.

Calcium sulphate is usually considered insoluble at temperatures of 300 deg. Fahr. This may be true in distilled water, but its solubility is raised by the presence of other substances even at temperatures far above 300 deg. Fahr. This is illustrated by the following analyses:

	Grains per U. S. Gallon	
	Analysis *A* Well Water	Analysis *B* Concentrated Boiler Water
Volatile & organic matter	1.30	4.20
Silica	.55	.45
Iron & alumina oxides	.15	trace
Calcium carbonate	3.25	1.00
Calcium sulphate	13.55	78.80
Magnesium sulphate	4.11	6.36
Sodium sulphate	.28	19.81
Sodium chloride	.99	10.55
TOTAL SOLIDS	24.18	121.17
Suspended matter	1.25	200.40
Free carbonic acid	1.43	none
INCRUSTING SOLIDS	21.61	86.61
NON-INCRUSTING SOLIDS	1.27	30.36

A is the analysis of the well water used for boiler feed. *B* is the analysis of the concentrated boiler water; boiler operating under 125 lb. pressure (temperature 352 deg. Fahr).

Scale containing calcium sulphate usually shows a laminated structure, which is probably due to the degree of concentration that must be reached before crystallization occurs. The structure would seem to indicate that a supersaturation is reached, followed by a rapid crystallization, and that be-

tween such periodic depositions of the crystallized calcium sulphate a constant deposition of other substances is occurring, and when these are markedly different, either in structure or color, they show well defined layers.

The following analysis *C* is that of a well water which would be considered by many an ideal natural water for boiler feed. This water has a total of 2.96 grains of incrusting solids, but the character of these solids is such that both scale and corrosion result from its use. Analysis *D* shows this water after concentration in the boiler, indicating that reactions have taken place, and the cause of scale formation, as well as of corrosion.

	Grains per U. S. Gallon	
	Analysis *C* Well Water	Analysis *D* Concentrated Boiler Water
Volatile & organic matter	.65	2.70
Silicia	.25	1.25
Iron & alumina oxides	.35	.65
Calcium carbonate	.27	1.25
Calcium sulphate	1.67	11.42
Magnesium sulphate	.15	.87
Magnesium chloride	.27	none
Sodium sulphate	none	4.62
Sodium chloride	.13	2.64
TOTAL SOLIDS	3.74	25.40
Suspended matter	.60	13.30
Free carbonic acid	.22	none
INCRUSTING SOLIDS	2.96	15.44
NON-INCRUSTING SOLIDS	.13	7.26

A water containing in solution calcium carbonate and magnesium sulphate is quite a common combination of scale-forming impurities, and when these are present in small quantities they are not generally considered objectionable, as the calcium carbonate is supposed to form only soft scale or sludge, while the magnesium sulphate when present alone is not supposed to form scale; but at the temperatures in the boiler, and with concentration, when these two substances are present they will react, forming calcium sulphate and magnesium carbonate. We thus get the most objectionable of all scale-forming salts, calcium sulphate.

The following analyses *E* and *F* show a water of this character before and after concentration:

	Grains per U. S. Gallon Anaylsis *E* Feed Water	Analysis *F* Concentrated Boiler Water
Volatile & organic matter	.35	.65
Silica	.35	1.20
Iron & alumina oxides	.20	.15
Calcium carbonate	1.00	1.25
Calcium sulphate	.58	3.71
Magnesium sulphate	.21	.12
Magnesium chloride	.11	none
Sodium sulphate	none	.60
Sodium chloride	.16	.46
TOTAL SOLIDS	2.96	8.14
Suspended matter	3.15	2.50
Free carbonic acid	.22	none
INCRUSTING SOLIDS	2.45	6.43
NON-INCRUSTING SOLIDS	.16	1.06

The reactions of the chloride and nitrate of magnesia with calcium carbonate is also quite common, resulting in the formation of scale, and also causing corrosion both below and above the water line. The following analyses *G* and *H* show water containing these salts and the results from the action of heat and concentration to change all magnesia salts to the corresponding calcium salts as well as the concentration of the scale-forming calcium sulphate.

	Grains per U. S. Gallon Analysis *G* Well Water	Analysis *H* Concentrated Boiler Water
Volatile & organic matter	.65	3.80
Silica	1.25	11.40
Iron & alumina oxides	trace	.15
Calcium carbonate	1.00	1.50
Calcium sulphate	.68	8.70
Calcium chloride	none	7.53
Calcium nitrate	none	22.78
Magnesium chloride	.53	.85
Magnesium nitrate	.48	none
Sodium chloride	1.32	66.89
TOTAL SOLIDS	5.91	123.60
Suspended matter	.15	2.95
Free carbonic acid	1.32	none
INCRUSTING SOLIDS	3.94	52.91
NON-INCRUSTING SOLIDS	1.32	66.89

From the above it will be evident that a water to be good must not contain either calcium sulphate or magnesium sulphate. Magnesium sulphate is also objectionable for another reason, for in the presence of sodium chloride, which is found in practically all waters, it may, after concentration at the temperature in the boiler, react with the sodium chloride, forming sodium sulphate and magnesium chloride; the latter then dissociates into magnesium hydrate, which is precipitated as sludge or scale and into hydrochloric acid, which corrodes the boiler. This is probably one of the reactions indicated by analyses *C* and *D*.

Magnesium chloride is always objectionable because it is easily dissociated into magnesium hydrate and hydrochloric acid. In waters containing much calcium carbonate the hydrochloric acid will form the calcium chloride and liberate carbonic acid. The nascent carbonic acid thus liberated is corrosive and the corrosion is increased by the presence in the water of oxygen absorbed from the air.

The dissociation of calcium chloride after concentration into calcium hydrate and hydrochloric acid is indicated in the following analyses *I* and *J*. The effect of heat and concentration on the magnesium salts is also indicated:

	Grains per U. S. Gallon	
	Anaylsis *I* Lake Water	Analysis *J* Concentrated Boiler Water
Volatile & organic matter	.35	2.90
Silica	.35	.45
Iron & alumina oxides	.10	trace
Calcium carbonate	1.02	2.02
Calcium sulphate	2.14	7.68
Calcium chloride	none	1.19
Calcium hydrate	none	.33
Magnesium sulphate	.93	none
Magnesium chloride	.32	none
Magnesium hydrate	none	.32
Sodium chloride	.10	12.77
TOTAL SOLIDS	5.31	27.66
Suspended matter	.05	.80
Free carbonic acid	.33	none
INCRUSTING SOLIDS	4.86	11.99
NON-INCRUSTING SOLIDS	.10	12.77

In the boiler the nitrates of lime and magnesia are very similar in their action to that of the chloride of lime and magnesia, and are therefore very objectionable. Magnesium carbonate is the least objectionable of the magnesia salts found in natural waters, yet it is frequently the cause of corrosion, usually indicated by pitting due to its dissociation and the concomitant liberation of carbonic acid.

It would seem hardly necessary to mention that any free acid is objectionable, yet in many boiler plants; acid waters are used and every known make-shift is employed to overcome the deleterious action of the acids. Iron sulphate is quite common, especially in our local water supplies. This substance at temperatures attained in boilers is easily dissociated, forming oxides of iron and liberating sulphuric acid.

The following analysis *K* shows a class of well waters very common in some parts of the country. Such waters often produce a considerable amount of very hard scale:

	Grains per U. S. Gallon Analysis *K* Well Water
Volatile & organic matter	.45
Silica	1.05
Iron & alumina oxides	.95
Calcium carbonate	2.14
Magnesium carbonate	.90
Sodium carbonate	1.08
Sodium sulphate	.43
Sodium chloride	.82
TOTAL SOLIDS	7.82
Suspended matter	.45
Free carbonic acid	.77
INCRUSTING SOLIDS	5.04
NON-INCRUSTING SOLIDS	2.33

On account of compound being used at this plant a sample of the concentrated boiler water was not taken, but a sample of scale deposited before compound was used shows the following analysis:

Calcium carbonate	20 percent
Calcium silicate	58 percent
Magnesium silicate	4 percent
Silica	9½ percent
Iron & alumina oxides	5 percent
Organic matter	3½ percent
TOTAL	100 percent

From the above it would seem that silica in some waters acts as a cement, forming a hard silicate scale.

Water of the following analysis *L* is one that is quite common in many sections of the country:

	Grains per U. S. Gallon Analysis *L* Creek Water
Volatile & organic matter	1.15
Silica	.45
Iron & alumina oxides	.10
Calcium carbonate	.34
Calcium sulphate	.50
Magnesium sulphate	.61
Sodium sulphate	.60
Sodium chloride	2.64
TOTAL SOLIDS	6.39
Suspended matter	1.95
Free carbonic acid	1.00
INCRUSTING SOLIDS	2.00
NON-INCRUSTING SOLIDS	3.24

Water as shown by this analysis rarely causes trouble from scale and corrosion in boilers operating at seventy and eighty pounds pressure at normal rates, but in a modern plant using water of this character a hard scale forms in the boilers and a great deal of trouble arises from corrosion, especially above the water line, requiring renewals of steam lines every few years.

From what has been said in reference to the various impurities common to our water supplies it must be evident to any engineer or chemist that to obtain economy in operation and maintenance of steam boilers a water supply should not contain any appreciable amount of suspended matter, or acids, and be free from the sulphates, chlorides and nitrates of lime, magnesia and iron. The carbonates of lime and magnesia

should be as low as possible for the best results to prevent deposits in heaters and to keep the sludge in the boilers at a minimum.

With a proper boiler feed water it is possible to operate boilers year in and year out without scale or corrosion in heaters, pipe lines or boilers and without expensive repairs.

Natural supplies of water that give such results are rare, hence some means must be employed to prevent scale and corrosion. That the problem of overcoming scale and corrosion is one that is forced upon the steam user is evidenced by the number of boiler nostrums and mechanical devices on the market for purifying the water, either in the heater or in auxiliary apparatus attached to the boilers.

None of these methods approximate the results that are obtained with natural, soft, clear, non-corrosive water. But by properly softening and purifying the water before feeding into heater and boiler, operating conditions with natural, soft, clear water can be practically equaled.

The proper softening and purifying of water will eliminate or neutralize any acid, will completely remove all permanent hardness and will reduce the remaining scale-forming substance to less than three grains per U. S. gallon and will also produce a clear effluent.

Any method that fails to produce these results is either faulty in the design and operation of the apparatus, or radically wrong in theory or application, or both.

With a properly softened water there will be no scale formed in heaters, pumps, pipe lines and other auxiliaries, because the salts of lime and magnesia will have been removed to a point below their normal solubilities, so that at the higher temperatures that may be obtained, without concentration, no accumulation of scale will occur.

Neither will such a water form scale or cause corrosion in the boiler. Scale cannot form even with indefinite concentration, for the small amount of lime and magnesia salts left in the water are of such a character that when precipitated, as a result of concentration in the boiler, only a slight sludge is formed, which can be kept at a minimum by proper blowing-off,

and no matter how long the boiler is in operation, on being opened it will have the appearance of having been whitewashed. By washing out with a good pressure or by rubbing with the finger the metal of the boiler can be exposed to view.

Corrosion cannot occur because properly purified water contains neither corrosive acids nor substances, which, in the boiler, could produce such acids.

Clean heaters and clean boilers will produce steam more economically than when insulated with scale; this is a truism not fully appreciated by power plant operators.

Fuel consumption measures the economy of a steam plant; and no matter how high the efficiency of the steam engine may be, the final test for efficiency and economy is measured by the heat transferred from coal to the water in the boiler.

Scale and corrosion greatly diminish the life of a boiler and the expense for repairs is almost in direct proportion to the amount of impurities in the feed water. Under these conditions it appears to be a great waste of effort to concentrate attention on the apparatus actuated by the steam to the neglect of that vital factor in the economical generation of the steam, the condition of the boiler, which in turn is dependent upon the character of the feed water, and in this day there is no excuse for not providing feed water of a proper quality, since the means for obtaining it are at hand.

DISCUSSION

Mr. B. A. Ludgate:* The experience on the Pittsburgh & Lake Erie Railroad, shows that a treated water may give perfectly satisfactory results in a stationary boiler, in either the water tube or fire tube type, while in a locomotive boiler, the results from the same water is so bad as to make the constant use of it impractical on account of foaming or priming. Probably the great cause of this difference is the design of the locomotive boiler, such as the close spacing of the flues, the relatively small area of the surface of the water in the boiler, the small amount of steam space above the water, forced firing and high steam pressure.

* Assistant Engineer, Pittsburgh & Lake Erie Railroad Co., Pittsburgh.

When our waters have been treated to what I may call the 100 percent rate, in which practically all the scale forming matters have been removed by use of lime and soda ash, much trouble is experienced from foaming, the amount of foaming depending on the amount of soda ash used, but it is probable that the soda itself is not the only factor, but simply one of many. Experience has shown with two locomotives using the same waters, one using the waters treated and the other untreated, that both had trouble from foaming; but not quite so much trouble from this cause with the raw as with the treated waters.

On account of the trouble from foaming, we have experimented with treated water using considerably less than full treatment, and about October 1st, 1909, the treatment was reduced to about 25 percent of full treatment for both soda and lime, with the result that in about three weeks, a great amount of trouble was experienced from leaking flues in the fire box, but there was freedom from foaming. The treatment was then increased to 50 percent of full treatment, and maintained at that rate for five months, which resulted in a smaller amount of leaking, with no foaming. The treatment was then increased to 65 percent with the view of further decreasing the amount of leaking. In order to derive the benefit of the increased treatment it will be desirable to remove the unusually large amount of scale that has formed with the low treatment, which can probably be done by increasing the treatment to the 100 percent rate for a week or so. During the summer and fall seasons, the river waters are much worse than in the winter and spring, and the 100 percent treatment may be quite satisfactory in the former seasons, and impractical in the summer and fall. There is possibly a medium treatment, somewhat less than the 100 percent, that will be the most satisfactory in winter and spring, and still lower rate of treatment during summer and fall—which can best be determined by experiment.

We have experienced considerable trouble from pitting of the boilers and flues with the use of treated water. This was most noticeable in 1908, a very dry year, the river waters being unusually bad, and when we were using the 100 percent rate of treatment, the pitting was apparently worse on new or clean boil-

ers than on boilers that had considerable scale on them. In one case the flues of a new locomotive were nearly all scrapped after a fourteen months service, while other yard engines, with scale on them, using the same water were free from pitting,—steel flues were used in all cases. This pitting from the alkaline water is also noticed in the softeners which all show much pitting on all surfaces exposed to the treated water, the pits being as much as $\frac{3}{16}$ inch in depth. The boilers, flues and sheets in the softeners and storage tanks, are all steel of various compositions and makes, but all show the pitting action.

Very dry weather was experienced in the summer and fall of 1908, and the first rains of January, 1909, washed down a very large amount of vegetable and other organic matter into the Monongahela river, where it remained for several weeks, before it was carried out by the heavier rains which followed, this vegetable matter was partly in solution and partly in suspension. The surface of the water in the raw water box of the softeners was covered with a lather, or foam, several inches in thickness, and the surface of the river below the dams, from shore to shore was covered with foam in the same way. During this condition of the river, very much trouble from foaming in the locomotives was experienced, and besides which, there was much trouble from leaking in the fire box. This leaking having been caused by an excessive accumulation of scale or mud, rather a mixture of scale and vegetable matter, which was nearly three inches thick between the flues, which of course prevented the water from having free access to the flue sheet and to the flues near the flue sheet. An analysis of this deposit showed approximately as follows:

Organic matter	45 percent
Iron and alumina oxides	23 percent
Silica	13 percent
Magnesium hydrate	14 percent
Calcium sulphate	5 percent

In general our few well waters contain more vegetable or organic matter than the river waters, but in the soluble form. It may be that this organic matter, more, possibly in the suspended forms is a large factor in causing foaming.

It has been noticed that boiler troubles have increased in a general way in proportion to the steam pressures carried, the greater the steam pressure, the more the boiler troubles.

THE AUTHOR: With reference to foaming due to organic matter, I know of several cases where foaming was attributed entirely to organic matter. But when feeding into a clean boiler a clear water with the scale forming matter reduced to as low a point as can be reached, there will be no trouble from foaming. There is always a way of removing a greater part of the organic matter which the water contains and I have yet to see a locomotive boiler or any type of boiler which is clean, fed with a properly softened and purified water, that will foam. But the water must be clear and the lime and magnesia salts reduced to a point where there will be a minimum of sludge forming material.

In reference to the matter of pitting, that would depend in my estimation largely on the analysis of the water that was found in the boiler, and whether there is not possibly a reaction between substances left in the water to liberate elements which will cause corrosion. Of course, there is possible corrosion due to oxidation, but in my experience with stationary and railroad work, I have yet to see a case where foaming or pitting could not be stopped.

MR. E. K. HILES: Regarding the new locomotive whose tubes pitted badly and were scrapped in about a year and the other locomotives operating on identical water without pitting, to which Mr. Ludgate referred, I would ask whether the motive power department made any effort to trace up the material in the tubes of these various boilers with a view of ascertaining whether the composition of the tubes themselves had any bearing upon the question?

MR. B. A. LUDGATE: To my knowledge they did not make any effort to trace that up. We usually get half a dozen locomotives or more at a time, and I presume all those engines had flues of the same material put in them. This new one happened to go to this place and others to other places. This particular one pitted very badly in that length of time and I did not hear of any others of that bunch pitting.

MR. E. K. HILES: The other engines that did not give trouble were on other shop orders?

MR. B. A. LUDGATE: Yes. I presume they were older engines and had a pretty good coating of scale on the flues to protect them. A water that would do for a new boiler would not work at all in an old one on account of dropping down so much of the old scale and dirt in it, causing foaming, so that in locomotive practice it is very hard to get a condition which would be ideal, considered in that way.

THE AUTHOR: I had occasion to investigate a case of pitting in which, of the two drums of a new water tube boiler, one showed a great deal of pitting and the other none whatever. Pitting appeared above the water line of this new boiler but there was no trouble anywhere else in the boiler. After some controversy with the boiler people they replaced the drum and the new drum has given no trouble from pitting. I was not able to get a piece of the material of the drum that was replaced, but under the circumstances it would seem almost conclusive that the fault was with the material in the drum and not with the water.

MR. C. D. CHAMBERLAIN: Referring to the last analysis given by the author I would ask Mr. Greth whether he considers the presence of CO_2 in the water as the cause of the corrosion. Some plants use soda ash only, for waters showing evidence of being highly acid when the softened water must carry considerable CO_2 into the boiler, and as far as I know there is no trouble.

THE AUTHOR: In some places there is more trouble from corrosion with carbonic acid than in others. In the particular plant I have in mind there was no trouble below the water line, it was all above the water line. The boilers were in fairly good condition. There was some scale but not an excessive amount. But in other cases where there is a small amount of carbonic acid left in the water it causes a great deal of trouble below the water line. There might have been some dissociation between some of the salts in the water that could not be traced. There is no way of determining the acid that caused the corrosion from the iron oxides left behind. The salts formed which produce corrosion are unstable under boiler temperatures, leaving only the result of

their action and no trace of the attacking acid in combination with the iron.

MR. C. D. CHAMBERLAIN: With an acid water, like our river waters; do you consider that the tendency would be to cause corrosion?

THE AUTHOR: I would say yes, because if you carry the soda ash treatment far enough to completely soften the water you will carry in your water a certain amount of sodium bicarbonate that will dissociate under boiler temperatures and liberate carbonic acid, and that, being nascent, is very corrosive.

MR. B. A. LUDGATE: In what part of the boiler would you find that the most likely?

THE AUTHOR: This would be more apt to occur in that part of the boiler where the circulation is sluggish, or above the water line. You are probably familiar with the old five drum Sterling boiler. Only a few of them were built. I have seen cases in which the back, lower drum was the only place showing corrosion, the rest of the boiler showing absolutely no sign of corrosion. The circulation in this drum is sluggish. Further, the water does not reach a temperature sufficient to drive off the carbonic acid, dissolved oxygen and other volatile acids. The remedy in this case was to introduce water free from carbonic acid or any substance which was likely to dissociate under boiler conditions to liberate acids.

MR. C. D. CHAMBERLAIN: By eliminating the soda ash?

THE AUTHOR: Yes, by eliminating soda ash treatment by complete softening, as such a treatment leaves in the water carbonate and bicarbonates which are dissociated under boiler temperatures.

MR. E. C. TRAX:* I have been more interested in water softening from the standpoint of the sanitarian rather than that of the engineer. In McKeesport we have been considering the potability of the water, the effect of the softened water on health and the saving in soap and plumbing compared to the conditions previous to the installation of the softening plant.

* Chief Operator, Municipal Filtration Plant, McKeesport, Pa.

It is a question whether it is advisable to soften a city supply to the extent of making it a very good water for boiler purposes. The alkaline taste is of course more noticeable in water made very soft, while if the hardness is kept above 6 or 7 parts per 100 000 this is not noticed except by a few persons whose taste is very sensitive or whose imagination is very largely developed.

You may be interested in knowing what results have been obtained in softening Youghiogheny river water on a comparatively large scale. During the fall of 1908, the condition of the river water was the worst on record. It contained 45 grains per gallon of the sulphates of lime and magnesium and 15 grains of free acid. The corrosive action of this fluid, which can scarcely be called water, on the pumps, pipe system and plumbing fixtures throughout the city was so severe that it became almost impossible to supply the city with water.

The plant was put in operation October 11, 1908, and of course afforded immediate relief from corrosion troubles and the city has since been supplied with a clear soft water free from harmful bacteria and suitable for every purpose.

I shall quote briefly from the annual report of the Water and Lighting Commissioners for 1909, which shows the results obtained during the year.

"The variations in the condition of the river water have been wide and sudden, changes in hardness of 30 to 40 parts per 100 000 having taken place within a few hours on several occasions.

"The hardness of the raw water has varied from 4.5 to 51.0 parts per 100 000 and the reaction from 6.0 parts alkaline to 21.0 parts acid. The average hardness has been 14.0 parts and the average acidity 3.1 parts.

"Except in a few instances the hardness of the filtered water has been below 10.0 parts per 100 000. The average has been 6.6 parts and the average alkalinity 3.3 parts.

"The river water has been alkaline on 35 days, neutral on 45 days and during the remainder of the time, 185 days, contained free acid."

This report shows that the filtered water is a pretty good

water for boiler feed and a number of firms are using it in their boilers with satisfactory results. There is no evidence of corrosion and very little scale forms.

In regard to foaming, the explanation given by Mr. Greth is borne out by our experience in McKeesport. When the softening plant was put in operation there was quite a large amount of old scale in the boilers throughout the city and considerable trouble with foaming was experienced. After the scale was removed, there was no further trouble from this source.

Mr. Ludgate mentioned the collection of white scale in the pipes and valves leading from the water softener. I might say that our water is filtered through sand after it is softened and we have occasionally noticed this white deposit of carbonate of lime in the pipe system. It has caused no trouble but it seems that filtration will not entirely do away with this.

THE AUTHOR: Nearly all the plants with which I am familiar are equipped with mechanical gravity or pressure sand filters. Where there is any deposit it is never over $\frac{1}{32}$ inch in thickness and it does not seem to get any thicker provided the treatment of the water is carried out properly. Whenever the carbonate of lime in the water is over 2 grains I find that scale deposits. If you keep the carbonate of lime below two grains, and the magnesia all in the form of hydrate, and the water clear, there is no trouble from deposits or scale in pipe lines. At least that is my experience.

MR. C. D. YOUNG:* I do not know that I can add anything to what has already been said unless it is a few words about costs which has not been touched upon so far.

I would like first to answer the question of Mr. Ludgate about organic matter. We had a queer incident at Xenia, Ohio. Trouble due to foaming was reported from our softening plant at Richmond, Ind. We sent our chemist to find out the trouble and on returning he said the difficulty was due to pumpkin juice being taken in with the water at Xenia. It seems that there was a canning factory above the pumping plant at Xenia where they were dumping their refuse into the water we were using so that we were getting a great deal of vegetable matter in the water,

* Assistant Engineer of Motive Power, Pennsylvania Lines West, Pittsburgh.

causing foaming, which the road men reported as due to the purifying plant at Richmond.

Another point mentioned by the author of the evening I want to touch upon from the buyer's standpoint, is fake water softening compounds sold under various names. We have found on analyzing many of those softeners that they contain, when in liquid form, large amounts of water, some soda ash, and a little tanning liquor, and one is paying in these compounds about 50c. a gallon for water. So I suggest to people buying liquid water softeners to have them analyzed and to see what they are purchasing. If buying it in cakes they will find it about the same thing only tied together with something to conceal the soda ash. Anybody purifying water by means of compounds whether solid or fluid will, I think, save about 90 percent if they will buy the soda ash straight from the manufacturer and not from the fellow that sells a compound.

The problem of locating a purifying plant is a difficult question to determine on railroads where most of the water stations are pumping hard water. Where you have 80 or 90 pumping stations to take care of it is hard to decide where you will put your first $12 000 or $15 000 to do the most good. If you ask for a large enough appropriation to equip 80 plants you may not get any. It has been our practice in locating new plants to consider largely the water consumption at the points where the plants are going in as well as the character of the water. In connection with the consumption of course we consider the amount of scale forming material taken in the boilers per day. If you have a location very high in scale forming material but the consumption is low, it would be well to look for some point where the water is better and the consumption high and then figure out how much scale forming material you are taking in per day at each point and you will generally find that the points of large consumption are points where you would naturally locate the first plants.

A company starting water softening does not want to buy a very big plant. We took as our starting point a place where the consumption was fairly high and the water quite hard. That plant has served its usefulness in that the consumption has out-

run the capacity and it has been remodeled to take care of the increased consumption at that point. Since that time, 1903, we have built larger plants and we are now buying about 800 000 gallons of water daily for locomotive use from the City of Columbus. It is costing us there about 10½c. per 1000 gallons for water, and we consider that a fair price considering what it would cost us if we had to pump and purify the water ourselves.

The cost of operating our various plants does not entirely depend on the design of the plant or whether we treat to obtain 5 grains per gallon, but largely on the consumption of water at the plant. One will have about the same fixed charges in putting in a 20 000 gallon per hour plant as with a 50 000 gallon plant. The difference in first cost is not in proportion to the increased capacity, therefore the plant of large consumption can be operated per thousand gallons considerably cheaper than the small plant.

In checking up the operation of our purifiers we patterned after a system established by Mr. Campbell on the P. & L. E. R. R., with such modifications as we found necessary to meet our conditions. When we first took over the control of operating the plants from a central point we found that most all the different manufacturers in the country of softening plants had had a chance to build plants for us and each manufacturer had a different system of testing and charging. We had to adopt some uniform system of testing waters to check the pumpers, and the general scheme of the P. & L. E. R. R. has been quite satisfactory without any considerable change.

It is always interesting to find out what you are getting for your money invested. In our plants we run about 3c. per 1000 gallons for water treatment, including besides maintenance and operation, interest and depreciation on the plant figured in at 10 percent, pro rate of the pumpers' wages and pro rate of superintendence. For this cost we have very materially reduced our locomotive failures due to steam troubles. When one considers the expense incidental to locomotives partly or completely failing in steam on the road, I believe our improved service alone in this respect would justify the increased cost of the

softened water. In addition to the improved service we think we have reduced our boiler maintenance. On one division we formerly obtained about 35 000 miles between the settings of boiler tubes on high pressure boilers. That mileage has crept up to about 55 000 or 60 000 miles between settings, so you see there is a very handsome profit obtained in flue mileage. In fire box life there has been about the same proportionate increase. Whether all this has been due to the purified water or whether it is due to our men becoming accustomed to the higher pressure engines and proper washing and blowing out of these boilers, we do not know. But, we think there is no question that the purifiers have paid for themselves especially in the service the boilers have and are giving us.

There are a few things about the designs of plants on the market which may be of interest, that experience has taught the buyer to look into carefully. The most essential thing I think is that the plant should be operated entirely from the ground. If you give a man getting about $60.00 a month a job where he has to climb a ladder two or three times a day he will not take care of the job as well as where he has it under his eyes and can look at it. It has been our practice since our first two plants to insist on the machinery being on the ground. This arrangement with a continuous system limits you to a pressure or closed design whereas the intermittent system readily adapts itself to ground operation. We have no intermittent types of softeners installed on our system.

In following up the performance of purifiers we find each year that we do a little better than the preceding year in reducing the grains per gallon in the treated water. We are now operating with an average of a little less than 6 grains per gallon in five of our plants.

As regards the liming up of the discharge pipes; this results from the fact that we are running water through the plant at a higher rate than that for which they were designed, for if you operate your plant above its capacity the chemical action cannot take place completely within the softener. This results in scale and sludge forming in the pipes, which precipitation is rather hard to remove.

We find our water softeners do not cause foaming. It is natural for an engineman or any one unfamiliar with water treatment to report trouble from foaming due to using softened water. We generally find, when the treating plants are at fault, which is seldom, that it is due to crowding the output of the plant or the filters being out of order.

The principal cause of foaming is due to an excess of suspended impurities in the boiler which have not been properly blown off. This suspended matter may originate from sludge from softeners, the loosening of scale due to using treated water, clay in suspension due to heavy rains and improper, or incomplete, washing out of the boiler. It has been our experience that a boiler water carrying high concentration of soda solution due to using treated water, which in addition has suspended matter, from any of the above causes, that foaming is very apt to result.

The purchase of soda ash and lime for our softening plants has developed the fact that although soda ash is very uniform in quality that the same is not true of the oxide of lime. Some lime has been received with as low as 65 percent available calcium for treatment, and for this reason as well as its deterioration we have been successfully using a hydrate of calcium which is uniform and does not deteriorate while in stock.

Mr. J. O. Handy: The subject of water softening has always interested me. Our company built and put in successful operation a municipal water softening plant and one of our many troubles in connection with that plant was the formation of scale at various places in the neighborhood of the softening plant, more especially on the valves of the pumping engine. The remedy which we finally applied was that of introducing a small amount of carbonic acid into the water by letting it fall in the form of rain for a distance of two feet in a carbonating box where weak carbonic acid produced by burning coke was passing. The cause of precipitation was thereby removed and there was no tendency to produce any deposit of carbonate of lime.

In regard to vegetable matter causing foaming, the term vegetable matter covers a great variety of substances. There is

no doubt that tannin compounds, approximately pure, will correct the foaming tendency to some extent.

Another point that has not been touched on very thoroughly is the burning out which sometimes happens when scale is dislodged at one point and lies for quite a time at another point, especially if subject to very strong heat. I know of a case where a mechanic left a wrench, inside the boiler after repairing it. Burning out took place at or near the point where the tool had been left. This has a special bearing on what may take place when softened water is first introduced into a boiler which is already badly scaled up. Cleaning out should be done at frequent intervals to remove the loose scale.

The matter of silica in the water is one that chemists generally ignore and I would like to ask how Mr. Greth removes silica.

The matter of fuel saving is an important one in the theoretical consideration of water softening. Scale is a first class insulator and there is no doubt that a great deal more coal is consumed in generating a certain amount of steam from the moment the scale begins to form. Tests have been made which show the effectiveness of a very thin scale, in increasing the amount of fuel required. But keeping the boiler in service, especially in the case of locomotives, is so much more pressing that the fuel saving has never come to any very definite point. At least, I have never seen any very complete data on fuel saving caused by the use of properly regulated water softening apparatus. Nevertheless it must be a very material amount.

THE AUTHOR: The removal of silica is not attempted in a water softening system except mechanically. I have always found that the silica is considerably lower in the treated water than in the raw water. In one analysis I showed the water contained about one grain of silica, and it was perfectly clear; after softening the water it ran between ¼ and ½ grain and the reduction was sufficient in that case to prevent trouble.

Speaking of the burning of tubes, I have some samples of tubes with me this evening (showing). Here is a tube from a boiler with less than $\frac{1}{32}$ in. scale. Looking down into the tubes of this boiler, which was a B & W, little piles of scale could be

seen. Here is a tube sawed right through at the point where one of these piles of scale lodged.

On the other hand, here is the case of a tube where the blow out was due entirely to scale but not to the piling up but apparently from the flame impinging more on one part of the tube than another, resulting in the tube failure. In this case, you will note that the scale was pretty uniformly distributed.

Mr. B. A. Ludgate: In connection with the pitting, with all our softeners I notice that the softeners themselves are corroding very badly. The first few feet after the water has received its lime and soda it travels downward five feet or so, and one notices at that point, particularly, a great deal of pitting. The pitting increases all the way down to the bottom of the softener and all the steel which is exposed to the treated water is badly pitted. In some places I have noticed the pits are as deep as ⅛ in. or more. These pits of course cover a very small area for each separate one, from the size of a dime up to a half dollar, these individual pits taking place every two or three inches.

In connection with the vegetable matter it might be that the foaming is due to certain sorts of vegetable matter. I noticed quite recently that our well waters or subterranean waters have a great deal more organic material than river waters in general. The time I referred to when a large amount of vegetable matter was in the Monongahela river, the matter was largely in suspension as well as in solution, probably both. I would like to ask Mr. Young if this pumpkin juice was matter in suspension or in solution.

Also I would like to know the number of hours pumped out of the 24 to get a cost, figuring in depreciation charges, of 3c. or 4 c. per 1000 gallons.

Mr. C. D. Young: So far as the pumpkin juice is concerned I think it was matter in suspension. It was refuse from a pumpkin factory and having never operated a pumpkin factory I do not know much about it. We found that by blowing off the boilers pretty thoroughly until we got rid of most of this refuse, it stopped the foaming. In other words, we applied the same remedy we always apply, insisting upon a thorough blowing out

at terminals, and if necessary on the road, through the bottom blow off cock, and this would permit the locomotive to get over the road. So I should say the vegetable matter was probably in suspension and not in solution. There may also have been considerable glucose or starch in with the material. If this was the case I should imagine that it would have been matter in solution as well.

As to how we obtain our figures as low as 3c. or 4c., I have our sheets here which give the details of cost of operation which shows that such is the case. (See tables herewith giving costs of operation of certain water softening plants for the year 1908, also Figs. 1 and 2 giving curves showing the hardness of the raw and treated waters at two of these plants). In one of the plants the man who is operating the softening plant is also baggage master, express, ticket and freight agent. So his salary is distributed and that reduced the labor at that particular point. This also illustrates the desirability of having the plant on the ground. For in this case by the time the operator would get half way up the steps a farmer would come along and want some freight out of the house and he would have to come down. Then perhaps when he got half way up again a local freight train would come along with goods to be checked and he would have to come down again. He is supposed to charge that plant at 7:00 o'clock but it might be 9:30 or 10:00 before he would get in his charge which would upset the results of purification.

At another point the man who operates the purifier is also a hostler and his wages are distributed between those two items. At another point the man is a wiper in an enginehouse and when he is not wiping engines he is purifying water and there his time is distributed. In other words, the labor charge is much lower than where you have a man doing nothing else but operating the plant. Summing up, at one plant where we are operating with a continuous system, operated from the ground, the fixed charges amount to .0088¢, operating cost .0207¢, maintenance .0018¢, pro rate .00014¢, making a total for the year 1908 of .0314¢. At that plant the man who operates the plant spends part of his time operating the purifying plant and part hostlering engines.

PLANT NO. 1—DETAILED COST OF OPERATION FOR 1908

ITEMS	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Average Per Month	TOTAL Per Year
FIXED CHARGES														
Interest 5%, Depreciation 5%.....	60.14	60.14	60.14	60.14	60.14	60.14	60.14	60.14	60.14	60.14	60.14	60.14	60.14	721.68
OPERATING EXPENSES														
All Labor Operating Plant.....	64.52	66.08	82.36	63.05	71.24	58.32	60.24	64.53	57.60	59.75	54.99	61.67	63.70	764.35
Cost of Lime	146.48	140.15	103.52	102.31	109.13	117.17	137.59	131.32	131.89	148.56	138.90	150.78	129.82	1557.80
Cost of Soda Ash.....	35.36	33.62	37.59	25.12	30.91	34.87	45.36	40.92	42.65	36.10	32.91	35.40	35.90	430.81
Other Supplies, Chemicals, Etc.....	117.04	53.08	63.43	63.72	61.58	64.37	64.06	66.91	64.31	67.00	63.73	68.08	68.11	817.31
MAINTENANCE														
Repairs to Structure—Labor.....		.87	.34	.97	4.97	.96	2.58	8.53	11.54	2.64	3.12	.31	3.07	36.83
Repairs to Structure—Material.....		.72	2.16	.04	3.07	.68	.68	1.02	6.12	3.22			1.48	17.77
Repairs to Machinery, Piping, Pumps, etc.—Labor	14.22	5.22	10.86	25.15	5.85	17.01	6.26	5.83	15.08	7.25	11.05	9.03	11.07	132.81
Repairs to Machinery, Piping, Pumps, etc.—Material	.04	1.00		.15	1.81	1.97	1.20	3.72	.09	5.48		.82	1.36	16.28
PRO RATA														
Total Pro Rata Charges.....	3.90	3.84	5.84	3.86	3.86	3.69	3.81	3.91	3.78	3.81	3.79	3.79	3.99	47.88
TOTAL CHARGES	441.70	364.72	366.24	346.51	354.56	381.92	393.20	588.83	393.20	394.01	368.63	392.02	379.29	4551.52
Total Thousand Gal. of Treated Water	10547.	10710	11774	10526	9780	8285	9436	8454	10550	11064	11301	11671	10342	124098
Total Number Hours Plant was Operated	698.	696	719.5	664.	732	687	659	734	679	721	710	740	703	8439.5
Total Thousand Gal. of Raw Water Pumped	11096.	10710.	11774	10526	10335	8285	9436	9124	10800	11064	11301	11671	10510	126122
Max. Thousand Gal. of Water Treated One Day.....	413.	347	439	489	423	432	408	445	470	407	426	439	428	
Average Cost of Lime per 1000 Gal. of Treated Water	.01389	.01308	.008792	.00972	.011158	.014142	.01458	.015534	.012501	.013427	.012291	.012919	.01267	
Average Cost of Soda Ash per 1000 Gal. of Treated Water	.00335	.00314	.003193	.002386	.003161	.004209	.0048	.00484	.004043	.003263	.002912	.003033	.00353	
Av. Cost Lime & Soda Ash Per 1000 Gal. of Treated Water	.01724	.01622	.011985	.012106	.014319	.018351	.01938	.020374	.016544	.01669	.015203	.015952	.01619	
COST PER 1000 GALLONS OF TREATED WATER														
FIXED CHARGES 005702	.005615	.005108	.005713	.006149	.007259	.006373	.007114	.0057	.005436	.005322	.005153	.005887		
OPERATING EXPENSES.....034455	.027351	.024367	.02434	.028104	.033160	.032561	.06158	.0281	.028146	.025708	.027241	.02914		
MAINTENANCE 001352	.000729	.001135	.002499	.001605	.002489	.001136	.002259	.003112	.001686	.001254	.00087	.00168		
PRO RATA 000370	.000359	.000496	.000367	.000395	000445	.000404	.000463	.000358	.000344	.000335	.000325	.00039		
Total Cost Per 1000 Gal. of Treated Water for 1908 041879	.034054	.031106	.032919	.036253	.043353	.040474	.045994	.03727	.035612	.032619	.03359	.03709		
Total Cost Per 1000 Gal. of Treated Water for 1907								.04673	.05685	.037112	.0532	.038431	.04646	

PLANT NO. 2—COST OF OPERATION, 1908

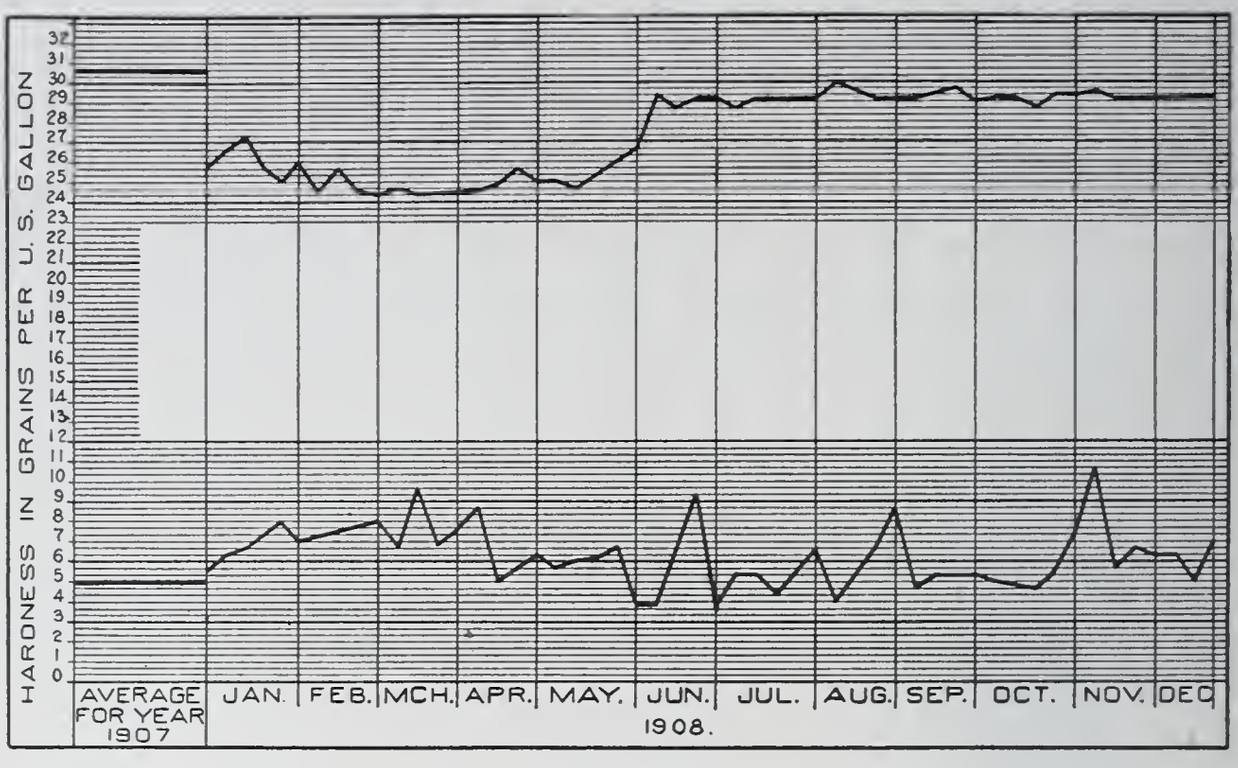
ITEMS	Jan.	Feb.	Mareh	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Average Per Month	TOTAL Per Year
FIXED CHARGES														
Interest 5%, Depreciation 5%.....	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	671.28
OPERATING EXPENSES														
All Labor Operating Plant.....	45.76	44.00	63.24	44.00	43.00	38.00	44.57	40.00	39.00	42.16	41.20	41.32	43.98	527.75
Cost of Lime	62.73	58.19	48.19	63.21	65.93	55.80	67.87	73.27	66.08	67.26	60.00	58.11	62.22	746.64
Cost of Soda Ash.....	39.38	54.00	51.79	79.38	88.11	71.75	77.44	84.78	89.92	90.28	73.80	76.08	73.06	876.71
Other Supplies, Chemicals, Etc.....	2.33	3.11	3.73	4.19	4.42	1.18	8.55	10.47	2.19	7.55	11.30	8.26	5.61	67.28
MAINTENANCE														
Repairs to Structure—Labor.....				.24				35.35		.77		20.36	4.73	56.72
Repairs to Structure—Material.....			1.10	19.49				20.00		.15		3.09	3.65	43.83
Repairs to Maehinery, Piping, Pumps, etc.—Labor	5.40	5.01	3.31	4.55	3.00	6.82	6.90	2.15	2.10	7.78	4.28		4.27	51.30
Repairs to Maehinery, Piping, Pumps, etc.—Material	4.33	.18	4.89		50.44	1.28	5.50	2.61	1.81	2.84	5.78	8.29	7.33	87.95
PRO RATA														
Total Pro Rata Charges.....	30.57	26.27	25.81	21.00	20.97	32.26	25.45	38.23	39.88	26.85	23.66	24.34	27.94	535.29
TOTAL CHARGES	246.54	246.70	258.00	292.00	331.81	263.03	292.22	362.80	296.92	302.38	276.66	295.79	288.74	3464.85
Total Thousand Gal. of Treated Water	9060	9111	7311.	9229	8994	8170	8662	9462	9565	9994	9166	8878	8967	107602
Total Number Hours Plant was Operated	744	696	588	720	744	684	726	744	720	744	684	661	705	8460
Total Thousand Gal. of Raw Water Pumped	9060	9111	9325	9229	8994	8544	8860	9462	9565	9994	9613	10275	9315	111784
Max. Thousand Gal. of Water Treated One Day	315	341	310	325	320	320	319	328	330	369	352	363	333	
Average Cost of Lime per 1000 Gal. of Treated Water	.0069	.0064	.0066	.0068	.0073	.0068	.0078	.0077	.0070	.0070	.0066	.0065	.0069	
Average Cost of Soda Ash per 1000 Gal. of Treated Water	.0043	.0059	.0066	.0086	.0098	.0088	.0090	.0090	.0093	.0090	.0080	.0086	.0081	
Av. Cost Lime & Soda Ash Per 1000 Gal. of Treated Water	.0112	.0123	.0132	.0154	.0171	.0156	.0168	.0167	.0163	.0160	.0146	.0151	.0150	
COST PER 1000 GALLONS OF TREATED WATER														
FIXED CHARGES	.0062	.0061	.0077	.0061	.0062	.0069	.0065	.0059	.0058	.0056	.0061	.0063	.0063	
OPERATING EXPENSES.....	.0166	.0175	.0228	.0207	.0221	.0204	.0230	.0220	.0206	.0208	.0204	.0207	.0207	
MAINTENANCE	.0041	.0005	.0013	.0026	.0060	.0010	.0014	.0063	.0004	.0012	.0011	.0036	.0022	
PRO RATA	.0033	.0030	.0035	.0022	.0023	.0039	.0029	.0041	.0042	.0027	.0026	.0027	.0029	
Total Cost Per 1000 Gal. of Treated Water for 1908	.0272	.0271	.0353	.0316	.0369	.0322	.0338	.0383	.0310	.0303	.0302	.0333	.0323	
Total Cost Per 1000 Gal. of Treated Water for 1907	.02387	.0306	.0248	.0303	.0217	.0247	.0255	.0215	.0255	.0299	.0255	.0319	.0263	

PLANT NO. 3—COST OF OPERATION, 1908

ITEMS	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Av. Per Month	TOTAL Per Year
FIXED CHARGES														
Interest 5%, Depreciation 5%.....	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	750.00
OPERATING EXPENSES														
All Labor Operating Plant.....	49.50	49.50	49.50	49.50	49.50	49.50	49.50	49.50	49.50	59.50	49.50	49.50	49.50	594.00
Cost of Lime	26.22	26.54	24.97	38.22	31.61	31.78	38.63	29.50	34.68	40.89	41.48	53.14	34.80	417.66
Cost of Soda Ash.....	24.52	29.39	35.03	41.85	33.45	32.63	37.13	36.98	34.01	38.59	42.15	53.46	36.60	439.19
Other Supplies, Chemicals, Etc.....														
MAINTENANCE														
Repairs to Structure—Labor.....														
Repairs to Structure—Material.....														
Repairs to Machinery, Piping, Pumps, etc.—Labor														
Repairs to Machinery, Piping, Pumps, etc.—Material														
PRO RATA														
Total Pro Rata Charges.....	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	60.00
TOTAL CHARGES	167.74	172.93	177.00	197.07	182.06	181.41	192.76	183.48	185.69	196.48	200.63	223.60	188.35	2260.25
Total Thousand Gal. of Treated Water	4606.	3885.	4590.	3416	3717	3701	4104	4190	4125	4568	4783	4979	4222	50661
Total Number Hours Plant was Operated	744.	651	744	624	696	611	744	744	720	744	672	744	703	8438
Total Thousand Gal. of Raw Water Pumped	4606	4417	4590	3996	4007	4255	4104	4190	4125	4568	5225	4979	4422	53062
Max. Thousand Gal. of Water Treated One Day														
Average Cost of Lime per 1000 Gal. of Treated Water	.00569	.00693	.00544	.01118	.00850	.00859	.00941	.00704	.00840	.00895	.00867	.01067	.00829	
Average Cost of Soda Ash per 1000 Gal. of Treated Water	.00532	.00754	.00763	.01224	.00900	.00881	.00882	.00882	.00824	.00844	.00881	.01073	.00804	
Av. Cost Lime & Soda Ash Per 1000 Gal. of Treated Water	.01101	.01449	.01307	.02342	.0175	.0174	.01805	.01586	.01664	.01739	.01748	.02140	.01698	
COST PER 1000 GALLONS OF TREATED WATER														
FIXED CHARGES	.01357	.01619	.01362	.01829	.01681	.01688	.01523	.01491	.01515	.01368	.01306	.01275	.01501	
OPERATING EXPENSES.....	.02176	.02714	.02385	.03793	.03109	.03078	.03052	.02768	.02865	.02543	.02783	.03135	.02867	
MAINTENANCE														
PRO RATA	.00108	.00129	.00108	.00131	.00134	.00135	.00121	.00119	.00121	.00109	.00104	.00100	.00118	
Total Cost Per 1000 Gal. of Treated Water for 1908	.03641	.04462	.03855	.05753	.03924	.04901	.04696	.04378	.04501	.04020	.04193	.04510	.04486	
Total Cost Per 1000 Gal. of Treated Water for 1907	.03641	.03417	.0319	.03261	.03463	.03301	.03386	.03504	.03430	.03754	.03649	.03841	.03416	

PLANT NO. 4—COST OF OPERATION, 1908

ITEMS	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Average Per Month	TOTAL Per Year
FIXED CHARGES														
Interest 5%, Depreciation 5%.....	98.72	98.72	98.72	98.72	98.72	98.72	98.72	98.72	98.72	98.72	98.72	98.72	98.72	1184.64
OPERATING EXPENSES														
All Labor Operating Plant.....	25.30	44.66	43.09	32.66	32.86	26.68	30.78	39.99	38.17	47.95	49.35	47.74	38.27	495.23
Cost of Lime	91.35	71.32	79.14	63.50	125.27	137.24	214.15	172.50	200.60	176.54	123.17	152.64	133.95	1607.42
Cost of Soda Ash.....	43.89	31.98	32.51	39.34	61.59	64.84	91.91	62.88	48.47	35.46	38.71	56.57	50.68	609.15
Other Supplies, Chemicals, Etc.....	.92	1.07	.69	2.07	.69	.70	8.13	.75	18.38	2.34		.97	3.06	36.71
MAINTENANCE														
Repairs to Structure—Labor.....											9.73		.81	9.73
Repairs to Structure—Material.....		.02		3.01							.37	4.19	.63	7.59
Repairs to Machinery, Piping, Pumps, etc.—Labor		2.73	.35	.48	5.10	3.00	10.03	34.96	10.66	.70	4.42	46.86	9.94	119.29
Repairs to Machinery, Piping, Pumps, etc.—Material		8.92	3.48	.04	.92		2.06	9.10	12.88	1.87	25.95	4.19	5.78	69.41
PRO RATA														
Total Pro Rata Charges.....	1.08	1.98	1.95	1.54	1.55	1.20	1.40	1.53	1.50	1.75	1.65	1.48	1.55	18.66
TOTAL CHARGES	261.26	261.40	259.93	241.36	326.70	332.38	457.18	420.43	429.38	365.33	352.07	413.36	343.40	4120.78
Total Thousand Gal. of Treated Water	15278.	14604.	13120.	12820.	12642.	9322.	11790.	8703	8928	11538	9054	11394	11599	139193
Total Number Hours Plant was Operated	657	661	656	641	684	530	666	494	525	621	409	727	606	7271
Total Thousand Gal. of Raw Water Pumped	15758	14604	13120	12820	13322	11898	11988	10863	8928	12294	13042	13086	12644	151723
Max. Thousand Gal. of Water Treated One Day.....	552	576	460	460	480	432	414	396	378	576	486	432	470	
Average Cost of Lime per 1000 Gal. of Treated Water	.00598	.00488	.00603	.00495	.00991	.0147	.01816	.01982	.0225	.0153	.0136	.0134	.0124	
Average Cost of Soda Ash per 1000 Gal. of Treated Water	.00287	.00219	.00248	.00307	.00487	.00695	.00779	.00721	.00543	.00307	.0043	.0049	.00459	
Av. Cost Lime & Soda Ash Per 1000 Gal. of Treated Water	.00885	.00707	.00851	.00802	.01478	.02165	.02595	.02703	.0279	.01837	.0179	.0183	.01703	
COST PER 1000 GALLONS OF TREATED WATER														
FIXED CHARGES 006466	.006762	.007522	.0077	.0078	.01059	.00837	.011343	.010948	.008559	.010899	.008660	.00880	
OPERATING EXPENSES.....010575	.010209	.011845	.01073	.017434	.0246	.02925	.031725	.033893	.022740	.023320	.022645	.02075	
MAINTENANCE ..... .00000	.000799	.000292	.000275	.000476	.00032	.00102	.005062	.002611	.000223	.004468	.00485	.00187	
PRO RATA 000071	.000136	.000148	.00012	.000126	.000129	.000119	.000176	.000166	.000152	.000182	.00013	.00014	
Total Cost Per 1000 Gal. of Treated Water for 1908 017112	.017906	.019807	.018825	.025836	.03565	.038768	.048307	.047618	.031674	.038869	.036293	.03139	
Total Cost Per 1000 Gal. of Treated Water for 1907 ..... .0214	.01813	.01525	.02127	.01771	.02023	.01626	.02418	.01956	.01575	.01975	.01927		


HARDNESS IN GRAINS PER U.S. GALLON
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AVERAGE FOR YEAR 1907
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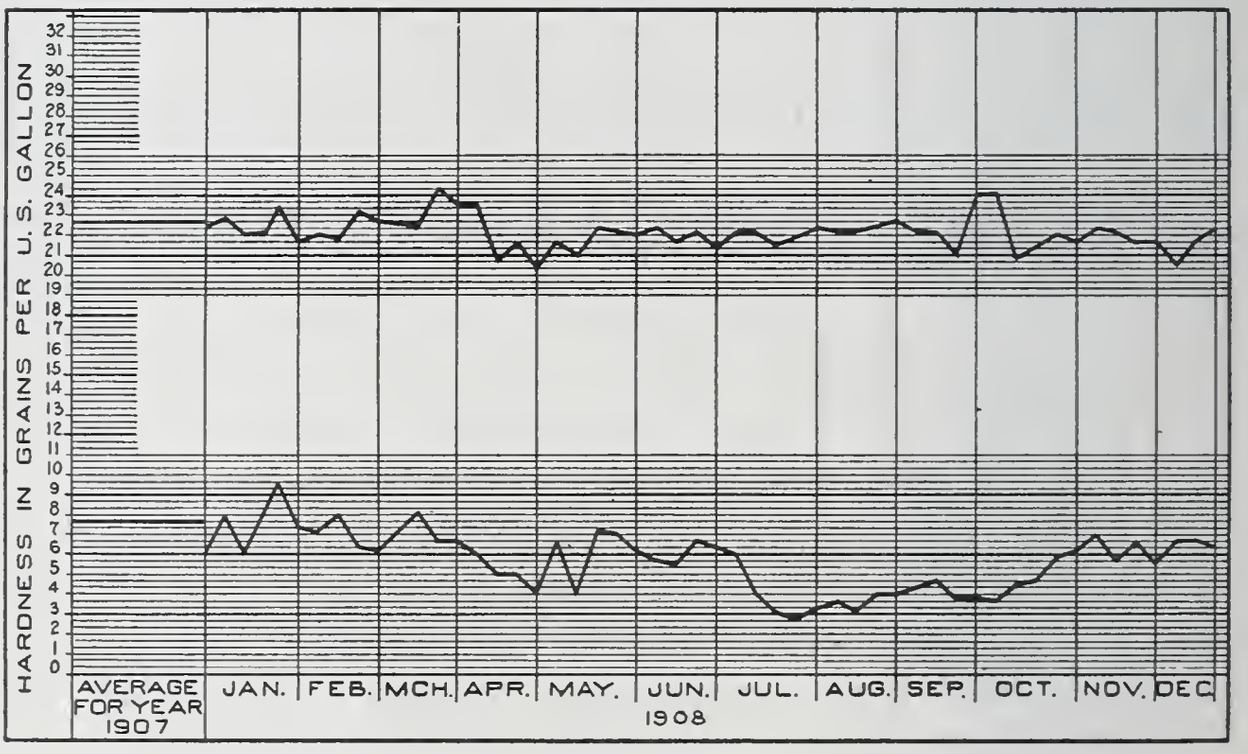
Fig. 1


HARDNESS IN GRAINS PER U.S. GALLON
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AVERAGE FOR YEAR 1907
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Fig. 2

The pro rate charge is the distribution of the laboratory expense for operating the chemical laboratory in checking our operators and the pro rate of the maintenance of way water supply superintendence. Where possible the purifying plants are operated by the maintenance of way department, under the motive power department supervision. This, I believe is different from other roads. Most roads have the matter entirely in the hands of the division engineer.

MR. RICHARD HIRSCH: I would like to ask Mr. Young to go into further detail in reference to relieving a foaming boiler by blowing off at the surface and at the bottom of the boiler.

MR. C. D. YOUNG: I meant blowing out from the lower blow off cock and not the surface blow off cock. We used to have surface blow off cocks but we do not have them any more because they were seldom used. I think they were originally put on to take off the oil, but the oil does not last very long after the fire box comes out of the shop and we have found that our surface blow off cocks were never very frequently used so we discontinued maintaining them and blow off from the lower blow off cock entirely.

THE AUTHOR: I conducted quite an investigation on the subject of blowing off from the bottom of the boiler as compared with the surface, especially with reference to water tube boilers and I found that the surface blow off removes more suspended matter as well as water showing a greater concentration than the bottom blow off. There is a considerable difference in the location of the blow offs in the different types of boilers.

In some of them the mud drum is completely out of the path of the circulation of the water and in others the water passes through the mud drum but in none of them does the suspended matter seem to have much of a chance to get out of the blow off openings. The circulation has a tendency to carry the suspended matter to the upper drums, and the surface blow off generally carries off more suspended matter; also the water in the upper drums seems to show more soluble impurities and the difference is quite marked. This applies to stationary boilers of the water tube type. This was covered by me in an article that appeared in "Power and the Engineer," August 31, 1909.

MR. F. A. NORTON:* My association with water purifying has been in connection with water for boiler use and more large-

*Chemist, National Canners Association, Aspinwall, Pa.

ly with water to be used in the packing industries. I have had a great many boiler compounds to analyze and they are generally of the description given by Mr. Young, usually a tannin extract with soda ash or caustic soda and occasionally a little mucillaginous matter or starch.

Of course in the food industries outside treatment of water is necessary for the removal of suspended matter and temporary hardness. It is desirable to do away with lime and magnesia as far as possible, as vegetables cook better in soft water. So a system of water purification which will remove suspended matter and temporary hardness is especially desirable, and this has been met to a certain extent by a system which I have had some opportunity to investigate.

The water is treated at a temperature of about 320 deg. fahr and about 80 lb. pressure. By heating to this temperature with subsequent filtration the temporary hardness together with the suspended matter and iron is very largely removed. Usually from 8 to 10 parts of temporary hardness will remain, but any in excess of that will be removed. While calcium sulphate theoretically is considered to be practically insoluble at this temperature, experiments with this apparatus show that a very large amount of calcium sulphate may remain in solution, so that for boiler treatment it is not so entirely successful without chemicals as for treating water having temporary hardness only.

Another method of treatment which I have recently had some opportunity to observe is filtering through bone char. Bone char is recognized to have a certain absorptive action for mineral salts in solution when filtered through the bone char. This is probably due to some inter-action of the salts which results, of course, in the more insoluble forms being given which are retained by the filter. The water observed so far contains a certain amount of sodium carbonate and the hardness consequently is temporary hardness, and so while the filter gave a very low figure for lime and magnesia it would require further work in order to state what would be done with water containing permanent hardness.

THE AUTHOR: I know of a number of cases of boilers using

water containing H_2S, and of one case in particular, where the water was in use for condensing purposes and gave a great deal of trouble from corrosion due to H_2S. The use of this water was discontinued on account of its corrosive action. In most cases, the amount of H_2S found in natural waters is very small.

Mr. F. A. Norton: I might state that in connection with the mechanical treatment at 320 deg. fahr., barium carbonate was used very successfully. The water after heating, which would remove temporary hardness, was treated by passing through a chamber or cylinder containing the barium carbonate where the sulphates of calcium and magnesium were very completely removed, the insoluble barium sulphate, calcium carbonate and magnesium carbonate resulting were of course removed in the subsequent filtration. It would handle an acid water very nicely also. There was some question of the applicability of the apparatus to the food industries on account of the fact that it is necessary to have a small amount of sulphuric acid, in combination of course as sulphate, in the water, to avoid some barium being carried into the effluent. Barium carbonate is theoretically insoluble but several parts to the 100 000 of barium carbonate would still remain in the effluent if an excess of sulphate was not left in the water as the water went to the filter during treatment.

But for boiler purposes very desirable results were obtained. The economical use of the barium salt together with the very complete removal of the sulphates of calcium and magnesium being secured.

Mr. C. D. Young: We have made some experiments with barium hydrate to meet acid conditions at a point where we did not have a softening plant. The results have been indifferent. It is pretty hard to say whether the cost of the barium hydrate would be justified in use. Our experience has only been experimental. I believe that you can accomplish everything that you could accomplish with barium hydrate with soda ash, if you take care of blowing off to take care of the suspended matter in the water. Barium hydrate costs about 3¢ and soda ash about .93¢ and you have to use about half as much barium hydrate as you do soda ash for results. This makes it an expensive chemical

to use and unless you cannot get results from soda ash and frequent blowing off, I do not believe you would be justified in its use especially as there is a question as to whether or not its presence in water makes it dangerous for drinking purposes.

MR. A. STUCKI: A superintendent of motive power in the West claims to overcome much of his trouble with leaky tubes by simply spraying the feed water upwards in the boiler. Does he secure his result on account of preventing the cold water from settling down to the bottom of the boiler and rushing back to the flue sheet or does the spraying have any influence on the formations of the scale?

THE AUTHOR: If the water was a carbonate water possibly throwing the water in the form of a spray into the steam space would suddenly heat it to a high enough temperature to precipitate all the carbonates, and the chances are that it did it in the form of suspended matter, or sludge, and thus possibly prevented scale. That is simply in line with other expedients.

I know of one case where in the operation of a Sterling boiler for one month the water was fed into the back upper drum and the next month into the mud drum. In this way it was claimed the scale was prevented. I do not believe that any of the heating devices inside the boiler or scale interceptors connected externally to the boiler can be effective against scale or prevent corrosion.

MR. J. O. HANDY: Are you able to form an intelligent judgment from analysis whether a water will form scale in the jacket of a gas engine or not?

THE AUTHOR: In all cases where there is temporary hardness there is scale and deposit. I have a number of samples of scale taken from gas engine jackets which were caused by waters with temporary hardness as low as 7 or 8 grains.

MR. J. O. HANDY: It would depend on the amount of free carbonic acid?

THE AUTHOR: It does, apparently. The same condition exists in connection with an ammonia condenser. In the hot pipes it would reach 220 deg. fahr. possibly, and in some cases the amount of scale deposit is low and in others with the same water, apparently quite high. Apparently the difference in carbonic acid would explain it, although it does not always follow.

NOTES ON CONCRETE CONSTRUCTION

By Robert A. Cummings *

It is somewhere printed that there is no parallel in industrial progress equal to that of the rapid development of the cement industry throughout the world. Engineers and technical authorities have scrutinized the subject from every angle resulting in its acceptance as a structural material.

A few years ago the Speaker presented the subject of Reinforced Concrete to this Society,† and at that time indicated some of its possibilities for use in engineering structures. Subsequent applications have fully justified the statements then made.

Numerous tests have been conducted and theoretical deductions formulated for use in designing structures. While some are tentative, the straight line formulae for beams have been almost universally adopted. Yet, Engineers in general have largely neglected to prepare their designs to meet the practical conditions facing the constructor. It is with this point in view that the Speaker would now invite your attention.

For construction purposes, concrete may be classified as plain, reinforced and structural. The application of plain concrete is frequently limited to gravity walls, piers, foundations, dams and similar bulk or mass work; whereas the term "Reinforced Concrete" has been applied to structures where any kind of metal reinforcement is embedded. This expression has been used indiscriminately. It has been made to cover plain concrete used for fireproofing or protection, etc. The Speaker has believed that the expression does not sufficiently indicate the

Presented at the regular monthly meeting of the Society, May 17, and published in the June, 1910, Proceedings.

*Consulting Engineer, Pittsburgh.

†Proceedings, Engineers' Society of Western Pennsylvania, 1904, Vol. 20, p. 577.

nature of concrete when applied to articulated structures. So that about eight or nine years ago during the discussion of a suitable name for the new material, he adopted and has since used the term "Structural Concrete." It is more definite and descriptive of its use. The term has since been adopted by at least one regularly published periodical. In the use of structural concrete, the metal should be distributed in small sections so that every pound is utilized in strengthening the concrete in compression as well as in tension.

RELATION OF CONSTRUCTION TO DESIGN

The interdependent relation between the construction and design is as important in structural concrete as in any other department of engineering. One can readily understand the crudeness of all our first efforts in any direction. But the amateur is very much in evidence in the field of structural concrete and seems thoroughly entrenched. Yet there is great latitude for individual variation and judgment in the design and use of this material. An Engineer has been described as "A man who can accomplish with one dollar that which any one can do with two dollars." Now the earnest hope of the Speaker is that we may avoid the reversal of this description. But, if we are to accomplish the best result, we must judiciously balance the composite parts of our problem. We cannot do this skillfully without sufficient knowledge to properly interpret the available data and the limitations of formulae. This is not all. Practical experience or knowledge as a constructor is equally necessary. If the economies of the materials as shown by our calculations are to be attained, it is just as important that they be combined with the practical conditions governing construction. These cannot fully, nor properly, be interpreted without intimate knowledge and experience in the methods of the field and a liberal endowment of that discriminating part of human nature frequently described as "Common Sense."

An Engineer would not venture to design an engine or a steel bridge without shop experience or full knowledge of the practical limitations in construction, so that it may be said with

the same emphasis that his work in structural concrete should be governed by similar information. Absence of this requisite is partly accountable for the variations met with.

The present age is noted for the quantity of books produced rather than the quality of the literature. This is particularly true of technical publications relating to concrete. For the most part they are made up of compilations or repeated data variously expressed by authors without practical experience. Further, these books have been a prolific source of confusion to the inexperienced practitioner. Consequently, he has become an easy victim to the shrewd salesman presenting the "talking points" of a variety of wings, knobs, twists, etc., given to the steel rods in order to find a market for same.

MONOLITHIC CONSTRUCTION

Only comparatively small structures are built truly monolithic because of the limitations of the amount of concrete that can be placed continuously. Yet the ordinary concrete building is considered monolithic on account of the intimate connection between successive day's work. Local or municipal regulations usually apply to monolithic work and govern the height of buildings and the permissible stresses to be used for materials, yet frequently fail to mention methods of execution or results to be secured.

The economical advantages of continuity in monolithic beams and slabs is dependent upon construction methods. The design should be governed by the amount of concrete that can be placed in a given work-period, or suitable provision be made for bonding the construction mechanically by steel rods embedded in the concrete made during both working-periods.

The shrinkage of monolithic concrete has caused much necessary and as well as much unnecessary anxiety. Shrinkage is largely attributable to the cement, but the amount of cement in the mixture and methods used in mixing and subsequent exposure have much influence. Shrinkage may be resisted by embedded metal rods. The Speaker well remembers an experience of eight years ago when testing some concrete beams 1 : 2½ : 5 gravel concrete 10 by 18 in. by 16 ft.

long reinforced in the bottom only. Some of these beams showed cracks near the center of the top side the next morning after being made. The extreme ends had raised from the sill of the form as much as one-quarter of an inch. The cracks may be explained by the shrinkage of the concrete at the top of the beam while setting, thus raising of the ends of the beams, until the stress due to the weight of the raised part of the beam was in excess of the tensile strength of its concrete when the beams cracked at the weakest point.

UNIT CONSTRUCTION

Just as construction methods are related to design so they can be modified to suit the particular type of structure. Hence the unit concrete member has been made independently and erected in position much in the same manner as structural steel is erected. A reason is not quite clear why this method has not come into more general use, except perhaps, that it is neither patentable nor salable, so it has been let alone to merit its own in due time. In its present development on account of numerous joints it should be limited to one-story buildings, such as round-houses, car barns, factories, etc.

The method is capable of combining most of the economics of design and construction. A great advantage is that the concrete is made and deposited in moulds at the ground level where men work more efficiently than from a high scaffold. The cost of forms is a minimum as less lumber is required because the forms are used more frequently with greater salvage. Again, the steel can be placed accurately with ease and at small cost, particularly when made at the shop in fabricated units, tagged and shipped to the work ready for placing in the molds. The cost of such steel is reduced to the minimum for placing, and is represented by the unloading only. The design is also improved by eliminating uncertain assumptions used for continuity in girders and slabs. All members being simply supported.

Against these advantages one must offset the difficulty of joining the unit members together over columns. The old concrete of the beams does not readily unite with new concrete

so that special provision is required at the joints to unite the members into a rigid structure.

The Speaker will later in the evening show upon the screen several progress construction views of two industrial plants in which this method has been combined with that of monolithic construction. This combination was desirable because of the necessity in these cases of rigid bearings for line shafting and moving machinery.

REINFORCEMENT

For the purpose of comparison, this is a phase of the subject that the Speaker approaches with some trepidation, not only, because he has long been identified with a particular method, but he does not wish to have his remarks misapplied. Mention has been made of the possible variation in the disposition of steel in the concrete by different designers in their laudable attempt to secure the most economical results. This has led up to a few individual developments characterized as "Systems." There has been much abuse of the word "System" in applying it to a variety of roughened rods. Yet there still survive by intrinsic merit certain features of the earlier methods. In a general way these methods may be divided into two classes—"loose rod methods" and "fabricated unit methods."

"Loose rod methods' may be summarized as consisting of a great variety of plain or deformed rods used and placed individually. This method is by far the most generally employed and most popular with contractors. The Speaker regrets to say it is even so with some Engineers, possibly because it is believed that the cost of the steel reinforcement is represented by the raw material.

The question of securing accurate placing of the reinforcement is a matter of small concern to the average contractor, for in his mind his contract is fulfilled by the mere embedment of the specific tonnage of steel rods in the concrete. Where? That is the business of the Engineer is his offhand answer. The contractor will use the cheapest material he can obtain under the plans and specifications. You cannot blame him for taking a business advantage of the loop holes conveniently

provided in the contract, when he has had to meet the stress of the competition of inexperienced or conscienceless bidders and owners. Besides, if loose rod systems are the accepted practice of specialist constructors, why should he not use similar methods? The lowest price is invariably the controlling factor in securing contracts and he can estimate the cost as closely as any one from indefinite or loose rod plans and specifications.

If the loose rod practice of the present time is here fairly represented, it behooves us to stop and reflect a moment and to ask ourselves whether or not a change for the better can be made.

For instance, let us more fully consider the question of misplaced reinforcement. The Speaker has been told by the Engineer having charge of the fire and loading tests conducted by the Bureau of Buildings of a large Eastern city, that, of all the tests made of the different concrete systems during the past few years, in 90 percent of them the reinforcement was misplaced. That is, when wrecking the building the rods were found in different positions from those shown by the plans for the test structure. These test houses cannot be called every day examples of work, they were carefully built for a special purpose to pass a special test. If therefore, the reinforcement is misplaced under such conditions, what may we expect from work done under ordinary contracts. If the testimony of the Speaker's twelve years of practical experience is of any value, he would state that reinforcement cannot be held in position except by a mechanical fastening for each rod, or by using the rods fabricated into a system of units made ready for placing and held in position in the concrete. The units should be sufficiently heavy to avoid any tendency to float, due to displacement in the semi-liquid mass. He does not feel called upon to show examples of the difficulties mentioned. They can be easily located by any one who desires such demonstration. But is the point important enough for our serious attention? Except for necessary covering to protect the steel, the only criterion may be said to be the strength of the beam, yet the strength is not seriously affected by a horizontal or lateral misplacement of the individual rods, if the rods are straight from end to end. But, should

the hydrostatic action of the semi-liquid concrete or the depositing, puddling and ramming raise the rods, which is the usual case, a very much less bending strength will result. A slight vertical raising of the rods on short spans might cause a reduction of 50 percent in the bending strength of the beams. This is a matter of vital consequence to the strength of any structure and commands our notice.

There is another contributory point in this matter of misplacement of the reinforcement and this can best be illustrated by an example from practice.

The writer's firm was recently invited to submit a proposal for an eight story concrete building about 100 ft. by 100 ft., according to detail plans and specifications prepared by a Western firm of architects and engineers. The reinforcement was designed upon the "loose rod" method. The beam and girder steel being bent up at the third points of the span and the shear steel disposed as vertical loose stirrups carefully shown on the drawings at small horizontal distances apart varying by fractions of an inch. This building was of common type and dimensions and required aproximately one hundred and forty two tons of steel reinforcement. According to the above mentioned plans there were over 18 000 loose stirrups, every one of which must be accurately placed by an ordinary laborer, and not only that, they must remain in position during the operation of the depositing of the plastic concrete. In addition to these stirrups there were over 25 000 other loose rods for which no guarantee had been provided for positioning, except the generous disposition of the contractor. It seems to the Speaker that the lack of restraint and the freedom from exacting work in the manufacture of the concrete and the placing of the reinforcement as at present in vogue accounts as much as anything else for its popularity. It is certain that grave results would have followed its abuse were it not for the one intrinsic merit, that, as designed, structures are frequently stronger than anticipated.

The Speaker cannot leave the subject of reinforcement without referring to the distribution of the steel in the concrete. Let us assume that our personal preferences are in favor of certain strength formulae, the symbols of which we are most

familiar with. The result of our calculations show say, three square inches of steel required for tension in the center of the beam. Eliminating the uncertainty of bond stress by providing mechanical anchorage at the ends of the rods, shall we use one, two, three or four or how many rods? The answer is not to be found by formulae; but, in the combination of experience and the lowest unit cost of materials.

The much discussed merits of deformed vs. plain rods may be summarized by the question: What is the best shape that will give the area of steel with the greatest bearing perimeter and permit a maximum amount of concrete to surround each rod within the fixed limits of an economical size of beam? An angular cross-section of rod will give less satisfactory results than a round one. Because, a square twisted rod will occupy a space in a beam equal to the diagonal of the square, and this is nearly one and one half times the diameter of a round rod. All deformed rods of the same nominal diameter and area occupy a greater cross-sectional space than round rods.

In the case of 1 in. and larger square twisted rods that have to be heated in order to be bent, there is an objection to their use because the annealing, due to heating at the bend, reduces the high elastic limit which is the only advantage gained from use of this particular form of rod. This fact is usually lost sight of and the practical result in a structure in which this form of reinforcement is used, is that a tension factor has been employed in the calculations of the reinforcement which is greater than is actually secured at all points in those rods which are bent hot. In such cases where negative bending moments occur at the bent portions of the rods, the discrepancy between the actual and the calculated strength is a matter worthy of serious consideration.

It might be well to bear in mind certain commercial conditions that are met with. Rods as received from the mill may vary 5 percent or more, from the nominal size. In fact, the Speaker's experience indicates the necessity of strenuous protest, as he has rarely found rods delivered in the exact manner ordered and this is particularly true of the exact number, size and length required. The disposition of the mill is to ship the

tonnage ordered. The accuracy of the shipment depends upon the counting by some mill laborer. This is a formidable objection to loose rod methods as used in the field. It might result in the substitution of sizes of those on hand for those that are required. Besides in loose rod methods a large number of rods are invariably left over on completion of the job. Frequently enough to pay for the differences in cost between a shop-made reinforcement and the loose rods. The actual labor cost of placing the loose rods in parts of the structure to be described later, was over six times greater than the cost of placing the rods in fabricated units. Again, one rarely receives the exact lengths ordered as there are thousands of rods to shear to various lengths and this is done by cheap, mill labor. Further, rods are handled by grappling devices in the mill while more or less hot, so that kinks are left in them and they are shipped in this manner to the job. Unless straightened at the shop these bends constitute objectionable features in the reinforcement.

In connection with the placing of reinforcement and holding the same in position, the most frequent cause of misplacement is due to the bending up or curving of single rods as they then become in unstable equilibrium and will fall over on one side in order to reach a state of stable equilibrium. Such rods are loose stirrups, turned up, or hooked, slab and beam rods.

There is another practical point for consideration. That is, the general use of "floating rods." These rods may be described as "gentlemen of leisure" that is, they are without visible means of support. The uncertainty of their final location makes them of questionable value.

The Speaker's firm recently estimated on a concrete structure, plans for which called for long span beams. The detailed drawings gave evidence of thorough preparation. Two ½ inch rods were shown along the top of the beam to be placed exactly three inches from the outer surface to the center of the rods. These rods were 50 feet long without support or attachment! The deflection of rods due to their own weight requires that their unsupported length be limited, in order to secure stiffness and a reasonable degree of immovability while the concrete is being placed. These are some of the objections to be mentioned

in connection with loose rods. They can be largely avoided by using fabricated shop-made reinforcement.

The Speaker can perhaps better illustrate such fabricated unit methods by reference to his own practice during the past few years. To be adapted to all the conditions that are likely to arise in practical work, such methods must comply with the theoretical essentials of design and meet the demand of practical constructors. They must be flexible enough to meet the preference for any shape of plain or deformed rod, and the reinforcement must be rigidly held in position from the molds while the concrete is being deposited. Each rod must be separated from its neighbor and completely embedded by concrete. The rods must be so disposed that the full benefit of the steel may be utilized for tensional stresses. Whether deformed or otherwise the rods should be mechanically anchored at their ends in the concrete in compression to make certain that there will be no slipping of the reinforcement and the full strength of steel may be developed.

The Speaker believes that his Looped Truss Girder complies with these conditions and has the practical merit of being a complete self-contained unit for each beam. It is shipped flat, so as to not become bent and to occupy a small space in transit. It may be described as consisting of rods shaped into rectangular frames and arranged in two rows. The upper row consisting of small tension rods that are curved up for the desired length at suitable points to form the shear members, the loops are thus anchored into the compression part of the concrete beam. The upper row is separated from the lower row by means of a small bar driven tight, through holes in flat band staples. The end of this bar being bent down the correct distance to support the steel from the forms.

His Hooped Columns have in addition to the necessary vertical steel, individual steel hoops attached to a vertical spacing member at uniform distances. These hoops may consist of flat or round steel. The flat steel hoops give about 5 percent greater core area for same weight of steel. The whole reinforcement is held rigidly together and forms a cage-like unit. Published tests have shown this form of hooping to be very efficient.

Mention may also be made of the Speaker's Chair Lock. This has been referred to in a previous paper before this Society,* and is used in connection with units for slab reinforcement. In the slab units the tension rods are formed into rectangular frames which are suitably spaced side by side and fastened to the shrinkage cross rods by the Chair Lock. This Chair Lock also securely positions the rods by supporting them from the forms. It is easily placed by simply pinching the top with a pair of heavy pinchers.

CONCRETE

Under the stress of present day competition, it is not surprising that Engineers have found difficulty in having their requirements for concrete complied with. But occasionally plans and specifications may conflict with the practical conditions and economics of construction. Further, it is not universally understood that the cost of concrete structures is largely dependent upon the relation of design to methods of construction. Yet, the Speaker has observed that the difference in prices named by bidders may be directly attributed to vague, indefinite and uncertain clauses, or omissions, in specifications. Obviously, where an essential is clearly detailed, there can be but little chance for variation or misinterpretation, so that other things being equal, the lowest bidder becomes successful. Again, does not the owner profit by competition between parties estimating from precise and clear information? It follows then, that business relations are improved and there is a greater public appreciation of technical efficiency.

Perhaps, there is no essential more frequently omitted from the specifications than the required strength value for the manufactured concrete. Specifications are usually elaborated in great detail covering physical and chemical properties of the cement, aggregates, proportioning, and preparation of the concrete. Would it not be desirable to insist upon securing a given strength value for the concrete within reasonable limits and leave the manufacture to an experienced contractor.

In the design of beams, the sizes is much affected by the

*Proceedings, Engineers' Society of Western Pennsylvania, 1909, Vol. 25, p. 505.

assumption for strength value. The strength for a given size beam may be almost doubled by the extremes of the assumptions now in use. Of course, in the latter case there must be an increase in the quantity of steel to balance the increase in unit compressive stress used for the concrete. On the one hand, by the use of very low unit stress in the concrete, we may get a beam, the dead weight of which is out of all proportion to the duty it has to perform. It is very desirable therefore, that we keep our unit stresses of concrete at such fixed values that will produce an economical size beam. Then again, it is not desirable to fix the unit stress in the concrete without reference to the use of the structural member. For instance, in *T* beams and slabs, a higher unit stress is permissable than in simple supported beams. The safe unit stress in hooped concrete columns may be a thousand pounds per square inch, whereas plain concrete is used as low as three hundred pounds.

While it has been shown that the strength of concrete increases with the amount of cement, it must not be forgotten that the difficulties with shrinkage are also increased.

The practice of making structural concrete so fluid that it may be conveyed through pipes by gravity is reprehensible in the light of present knowledge of the loss of strength, separation of aggregates and escape of cement with surplus water, although the cost of depositing the concrete may be diminished by such methods.

On account of the extensive scope of the subject, the Speaker has omitted any reference to the development of metal forms for concrete members; and to the necessary organization for carrying out economical methods of construction.

COMBINED UNIT AND MONOLITHIC METHODS OF CONSTRUCTION USED ON THE PLANT OF THE NATIONAL CASKET COMPANY, AT ASHEVILLE, N. C.—1909

BY ROBERT A. CUMMINGS *

This plant comprised three separate buildings, a mill building, power house and dry kiln. The mill building is a one-story factory 80 ft. by 280 ft. with a monitor 40 ft. by 240 ft.. The

*President, Cummings Structural Concrete Co., Pittsburgh.

dry kiln is 80 ft. by 137 ft. In connection with the dry kiln are two transfer platforms, one between the mill and kiln buildings, 39 ft. by 80 ft. and the other at the north end of the kiln building, 36 ft. by 80 ft. The power house is a one story building 47 ft. by 100 ft.

All buildings are constructed of structural and plain concrete and brick as follows:

The structural concrete was mixed in approximate proportions of 1 : 2 : 4 and the plain concrete 1 : 3 : 6.

Mill Building—The foundation walls are of plain concrete. The columns, beams, girders and roof slabs of structural concrete. The columns, the cross and the main girders are of monolithic construction. The columns are spaced 20 ft. center to center. The cross and intermediate beams are spaced 5 ft. on centers. The intermediate beams are of unit construction.

A brick curb surrounds the lean-to. This is backed with a concrete gutter to which the flashing is secured. The conductors lead down inside of the building and through the foundation walls below the floor line. The entire building has a 3 inch finished concrete floor.

Kiln Building. The foundation walls are of plain concrete. Five longitudinal 13 in. brick walls 20 ft. center to center, divide the building into four kilns. The concrete roof is of unit construction consisting of concrete beams, and slabs resting on top of the beams which are supported by the brick walls.

Power House. This building is of monolithic construction except the roof slabs which were cast on the ground and placed.

CONSTRUCTION PLANT

The layout of the construction plant was as follows: Two separately operated mixing plants were used, one for monolithic work being located between the mill building and dry kiln and the other for the separately molded members situated at the slab yard south of the mill building. Cement, sand and stone for the main mixing plant were delivered on the railroad siding and unloaded along side the track.

Power for the main plant was furnished by a boiler located west of the dry kiln along the siding where fuel could be

conveniently unloaded. A No. 2 Ransome mixer was used at this plant. The sand and stone were shoveled into one yard, industrial type cars divided by a partition to correspond to the proper volume of aggregate. Portable track was laid along the material pile and the cars, after being loaded, were run to the foot of an incline track leading to the charging platform. A cable operated by a hoisting engine was then attached and the material hauled to the charging platform and dumped into the hopper. A stock of cement was kept on the charging platform and one man attended to the charging. Four men were used in loading the aggregates. Water was supplied from a tank located above the mixing platform. Close to the mixer was an elevator used to hoist the concrete, which was delivered for the monolithic superstructure in two wheeled buggies.

The power house was poured first, with one setting of forms. A runway led from the elevator to this building at an elevation slightly above that of the roof. Only a small amount of concrete was placed in a column at a time and well puddled. Pear shaped rammers being used for this purpose. All columns were poured to the elevation of the bottom of the brackets, then allowed to settle and shrink twenty-four hours. The girders and beams were then poured.

After about a week the side forms were removed, except under the girders which were left supported by posts for at least three weeks.

In constructing the mill building one main runway extended from the elevator to the south end of the building. This runway had two decks, one at the elevation of the top of the monitor and the other at the elevation of the roof of the lean-to. Work was begun at the south end of the lean-to and monitor. One setting of forms covered about four bays and all forms on columns and sides of beams were removed after three or four days. Bulk-heads were placed for joints in the middle of the beams.

The runway had a slight grade from the elevator to lessen the labor of wheeling full buggies but not enough to interfere with the return of the empties.

Near the north end of the building is an elevator pit ap-

proximately 20 ft. square and 13½ ft. deep. Two cylinder pits extended 7 ft. deeper. All the walls, floors and cylinders are plain concrete, the floor being an inverted arch to resist hydrostatic pressure.

On account of the rather low elevation of the site and the adjacent river, considerable water was encountered in the elevator pit in the form of seepage and springs. In order to make the pit water-proof special precautions were necessary.

When the excavation was completed, the lower part being in rock, three springs were found in one pit and two in the other. In order to relieve the pressure while concreting, the water was taken care of by steam siphons in the following manner. The springs in each pit were drained to one low spot by small gutters which were filled with coarse broken stone and covered with empty paper bags to prevent the concrete from closing up the drains. A steam siphon was then placed at the low point and concreting begun. Two of the springs were well up on the side of the pit, but as the concrete level was raised more stone was placed along side of the pit allowing the spring water to flow down to the siphon. The jets were concreted in and were pumped for several days until the concrete had a good set. The pipe was then unscrewed above the concrete and a cap put on, thus sealing the foundation.

The floor of the mill building was filled with earth to within about six inches of the final floor level, one yard industrial cars and portable track being used for the filling. The fill was wet down and well tamped and three inches of sand placed on top as a bed for the concrete floor. The concrete floor was divided into 10 ft. by 10 ft. squares, each requiring about a cubic yard of material.

Most of the floor was laid in freezing weather so that it was necessary to heat the building. Two brick salamanders, one on each side of the building were fired continuously, coke being used as fuel. In extreme weather fires were kept burning in metal wheelbarrows, which were easily shifted as required. A temperature between 30 and 35 deg. above zero was thus maintained through the work.

The Cummings System of steel reinforcement was used ex-

clusively. All steel was shipped in shop-made units tagged and ready to be placed in the forms with the exception of the column reinforcement, which was shipped knocked down. All the steel was unloaded at the south end of the mill building near the slab yard and protected by a 50 ft. by 54 ft. shed.

The girder, beam and slab units were tagged with a letter and number corresponding to that on the drawings to insure the proper location of steel. This was also a great aid in checking the steel received.

As soon as the forms were completed and cleaned the steel was quickly placed by common labor under the supervision of the steel foreman, no work being delayed on account of placing of the steel.

Each unit was provided with Cummings patent Chairs to hold the reinforcement off of the forms, thus insuring the correct position of the steel in the beams and slabs.

Mill Work. The mill work was of factory style, frames shipped knocked down. These were put together under the steel shed where they could be protected until needed, when they were properly set and secured by the nailing strips in the girders above.

Roofing. As soon as all the unit slabs were lined up and grouted along the outer edge of the roof, a brick curb was laid in cement mortar and a concrete gutter was laid against the brick and sloped to the conductor heads. On completion of the grouting of slabs and placing of the curb and gutter, the standard 3 ply tar and stone chip roofing was laid.

SEPARATELY MOLDED MEMBERS

The cross beams in the monitor roof and the beams in the dry kiln and all roof slabs for the three buildings were separately molded on the ground and erected.

For this purpose a slab yard was laid out just south of the mill building. The yard was approximately parallel to the railroad siding and about 40 ft. distant. The overall dimensions were 190 ft. by 90 ft. On each side of the yard were three longitudinal rows of slabs five feet six inches wide, the middle being taken up with a row of beams about 20 ft. wide. The

longitudinal alleys were five feet wide. A little to the north of the middle was a transverse alley six feet wide, which divided the yard into two sections. At the end of this alley, near the track, was the concrete mixing plant, tool house, cement and steel sheds. Industrial track was laid throughout the length of all the alleys and provided with turntable crossings and switches.

A Ransome mixer was used here, power being furnished from a boiler located directly opposite on the other side of the siding. A small portable saw mill was also located across the railroad siding and driven by a steam engine.

The mixer was set up so as to discharge into cars at an elevation of about three feet above the track. A charging platform was built around the hopper and an incline constructed running about 50 ft. to the south and along side of the material which was unloaded from the siding. Nearest the mixer was the sand pile about 40 feet long and the stone pile extended 80 feet further along the track.

For depositing the concrete small cars were used. They were hexagonal, three feet across and six inches deep with a trough ten inches long on each side and closed by small stops, which were removed when depositing and the material pulled out with hoes. See Fig. 1.

The yard was nearly level so that a small amount of grading was necessary. For the first slabs made three feet by six feet, concrete bottoms approximately two inches thick were laid on sand. Later these were found unnecessary and the first slabs made were laid on sand leveled off, a layer of paper placed on it and the first slab cast on this paper.

The forms were made of two and three quarter inch stock, three inches wide. A frame was made the size of the slabs, the inside being beveled so that the side of the slab with the larger area was on top. When the form was removed and put together again, the lower side, being of smaller area, allowed it to be placed on top of the slabs already cast.

The sides of the forms were longer than required, to allow the forms being used for a few of the longer slabs. The forms were held together by rods across each end with nuts which could be loosened for removal of forms. All forms were

greased to facilitate removal.

The number of forms used was sufficient for a maximum day's run, and the proceedure was as follows: For the first pour, after covering the bottoms with paper, the forms were bolted together and placed on the bottoms. The steel slab units were then placed near each slab form. This was a short operation as all steel was in units and marked for placing.

Fig. 1

The concrete, transported in the cars mentioned above, was raked into the forms, tamped and leveled off. The steel was then embedded in the top of the slab as cast, and the surface slightly troweled. It will be noted that the slabs are cast upside down.

On the following days the removing and replacing of forms and the depositing of concrete were continuous and simultaneous operations. After one day's set, the forms could readily be removed by loosening bolts. Paper was then placed between the slabs to break the bond. This being done, the steel unit was placed near by, ready for the slab, and the concrete gang followed with their work.

The beams were cast in the slab yard, the molding being done simultaneously with the roof slabs. The beams averaged nine inches by eighteen inches by twenty feet.

Six lines of four inch by four inch sills were laid parallel to and between the industrial tracks to support the bottoms of the beam forms, which were laid at right angles to the four by fours. The forms were made for alternate beams and so placed

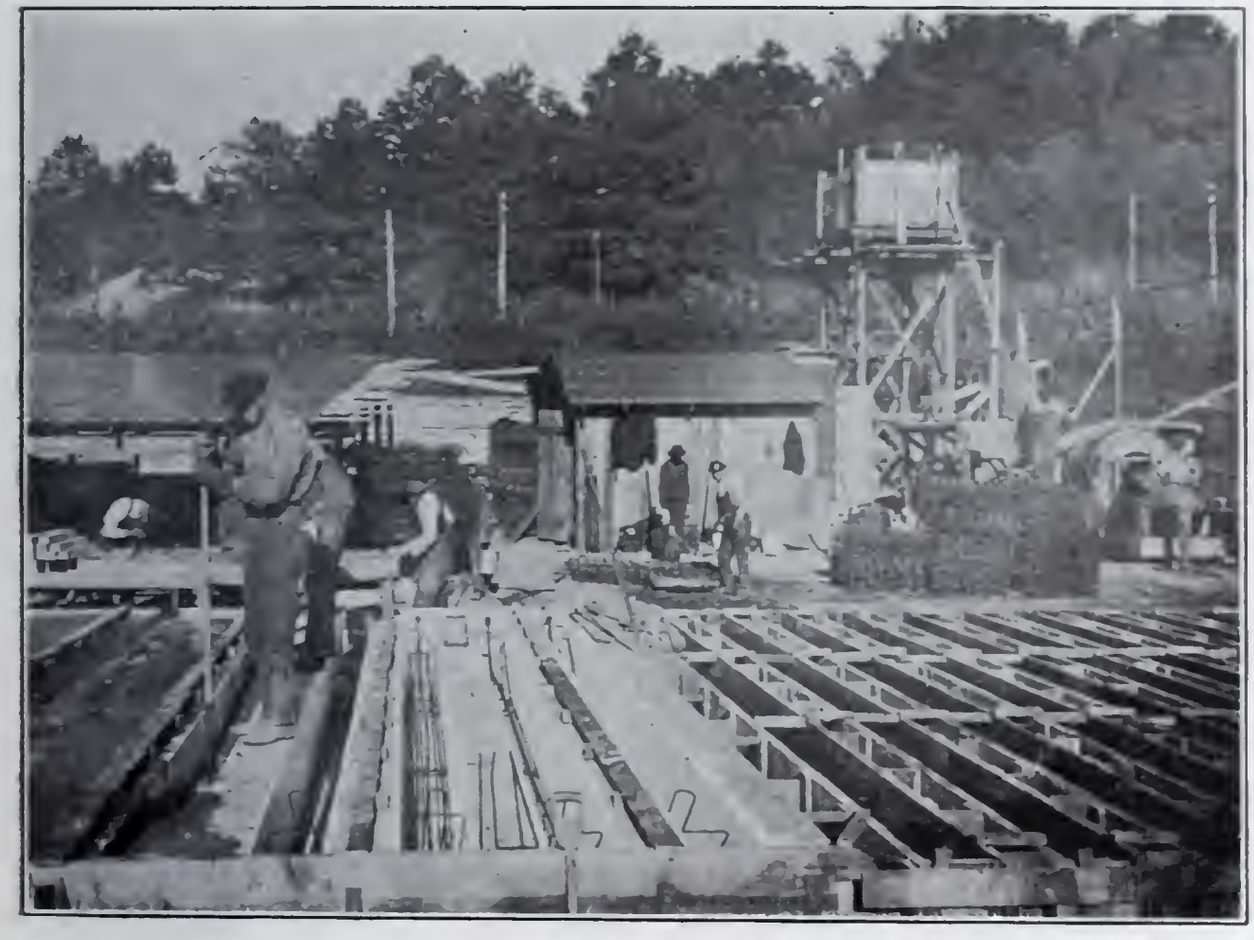

Fig. 2

that on the molding of alternate beams and the removal of forms, the intervening space was just the required width of a beam. The bottom and end forms were then set between the beams already cast and the sides of the latter whitewashed for use as the sides of the forms. Another set of beams was then molded. See Fig. 2.

The bond between the adjacent beams was slight on account of the whitewashed sides, most of them separating on the driving of a wedge at the ends and along the top. In a few cases, however, it was necessary to jack up one end slightly to break them apart. See Fig. 3.

On removal the first set of forms, the sides and ends were at once reset, additional planks being necessary only for the bottoms.

As soon as the forms were ready the steel units were placed. The reinforcement for each beam was a shop fabricated unit delivered ready for placing and tagged to designate the proper beam. Two men carried the steel from the stock shed nearby and placed it in the form. Thus the placing of steel for all beams occupied but a few minutes.

Fig. 3

The reinforcement was held off the bottom forms by Cummings Chairs, the proper fireproofing of the steel being thus insured without the use of loose hangers.

Concrete cars were run along each end of the beams and the material pulled out into the beams with hoes. It was then well rammed and troweled smooth along the top.

After the slabs and beams had had a set of about three weeks, the erection was begun. This was handled by the slab yard crew, two extra crews, under sub-foremen being added later on in the work.

The power house superstructure being the first poured, the slab yard program was so arranged that the slabs for this building were the first ready for erection.

Several schemes were tried out for moving and erecting the slabs. At first a heavy plank runway was laid extending from the yard up an incline into the mill and across to the power house. A low truck with wide wheels was built to hold from three to six slabs, which were taken by hand from the piles and placed on the trucks. The truck was then hauled by the hoisting engine cable along the runway to the power house where they were unloaded and piled twelve high at different locations in the building ready for placing.

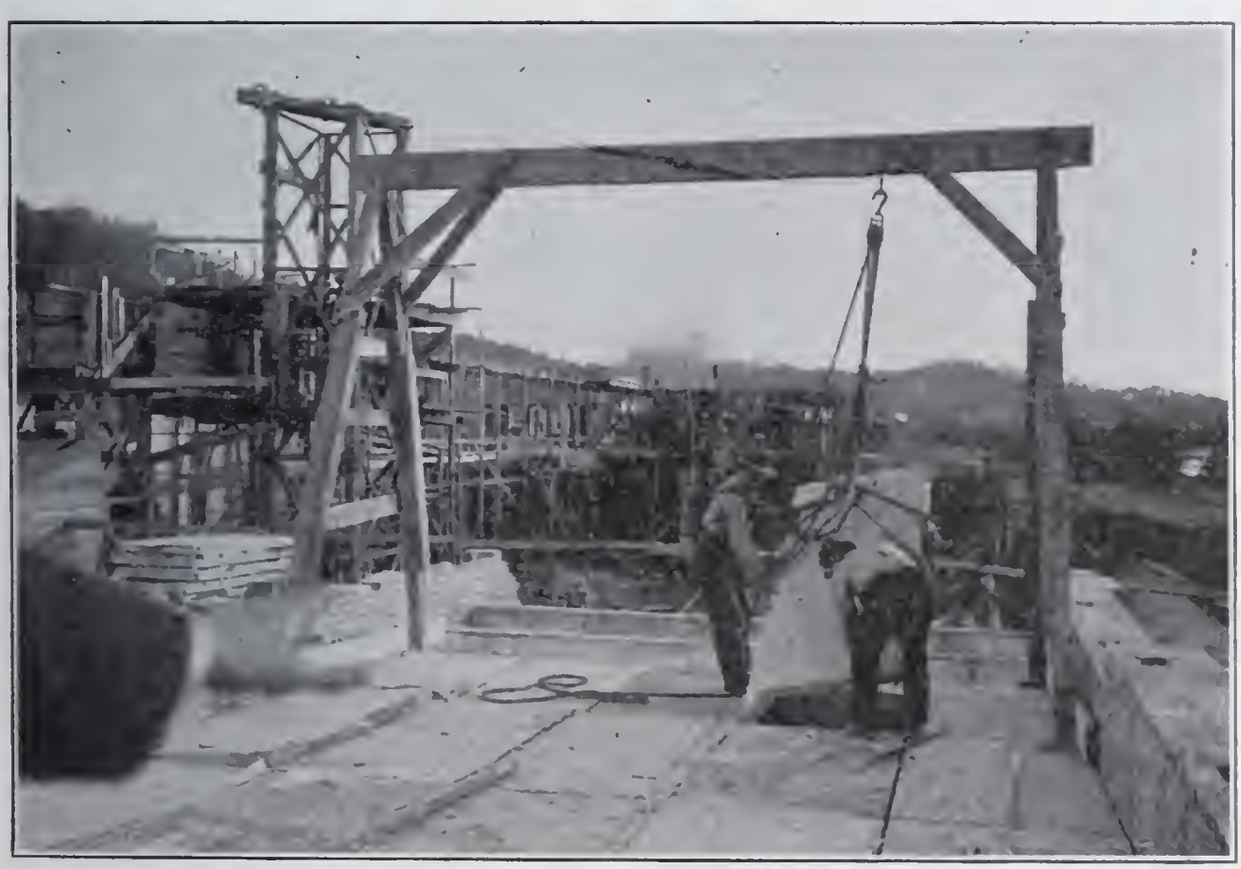

Fig. 4

After several experiments, the method of handling slabs finally adopted was as follows: For loading slabs a gantry was erected seven feet high and long enough to span a pile of slabs and the adjacent track. A small track was attached to the top of the gantry along which a sheave with rigging to carry the slab traveled. This slab rigging consisted of a five inch triple

block and line, to which were fastened four long hooks. To load a slab the traveler was placed over the slab pile, two of the hooks placed at each end of the slab which was clear of the pile and the traveler moved along until over the car and the slab lowered. The gantry was light enough to be easily moved by hand from one pile to another as required. Trucks and narrow gauge track were used for moving the slabs and beams.

For unloading, a double block attached to the beams of the building and a line with hooks were used, the slabs being hoisted clear of the trucks, swung over the pile and lowered. In piling the slabs, spacing strips were placed under each end.

The best way to erect the slabs was found to be as follows: A gantry was erected consisting of two *A* frames about five feet apart, braced together and supporting a cross piece to which was attached a double block. The *A* frames were about eight feet wide at the base. See Fig. 4.

This gantry was placed across the beams of the building which were five feet on centers and the slabs were hoisted up between the beams inside of the frame, swung into position and lowered.

A horse was used for the hoisting, the snatch line passing through a single block on the ground and a double block at the top of the frame. One man on the ground fastened the line around the slab and two men on the roof released and set the slab. They were set approximately when first placed and later were lined up and grouted. The grouting was placed in the groove left between the beveled edges of the slabs and slightly troweled.

The lower edges of all slabs were pointed with mortar. For this work traveling platforms were constructed and run on two lines of portable track. Three or four men worked on each platform about 200 sq. ft. of slabs being pointed at each position of the traveler. One traveler was used for the lean-to in the mill building and another constructed for the high work on the monitor roof. See Fig. 5.

The same method was used for moving and erecting slabs on all buildings. The dry kiln slabs were taken through the mill building on the portable track. Switches and curved track

were used in moving slabs to all buildings so they could be distributed to the different locations approximately beneath their final positions on the roof. See Fig. 6.

The moving and erection of beams was more difficult, each beam weighing 1¾ tons. The method adopted was as follows: The loading of beams was done with a beam gantry. Two towers were constructed about 15 ft. high and 5 ft. across the base and mounted on the trucks of industrial cars. One

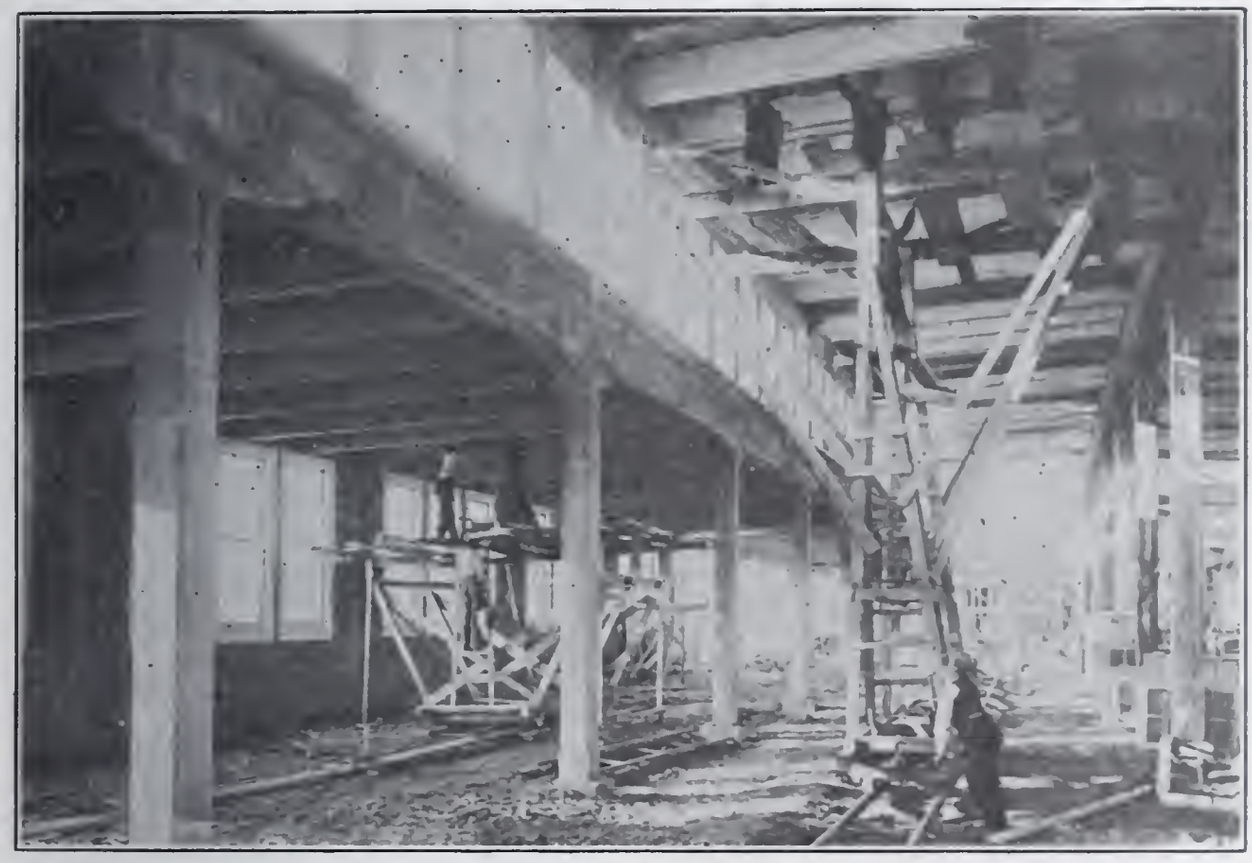

Fig. 5

truck with a tower was placed on the track running along each end of the beams. A 30 ft. *I* beam spanned the row of beams and connected the towers moving along the tracks. From the middle of the *I* beam a two ton triplex block was suspended, to which was fastened a bridle made out of two planks, two inch by ten inch, on edge, spaced two inches apart and bolted together. This was hung by means of a ⅝ in. chain from each end to a three inch by one half inch ring, which engaged the chain of the triplex block. The chains and tongs used to lift the beams were suspended from each end of the bridle so that the force applied was at each end and at right angles to the beam.

The first operation was to remove the bottom forms. To do this the gantry was placed directly over the beam and the bridle lowered. A large pair of tongs made out of 3/8 inch by 3 inch wrought iron and suspended from each end of the bridle, gripped the beam and raised it a few inches, the tongs being round pointed to avoid cutting into the concrete. The bottom form could then be easily removed. The beam was again lowered onto the 4 by 4 stringers and a chain placed around each end. It was then raised by the triplex block clear of the other beams,

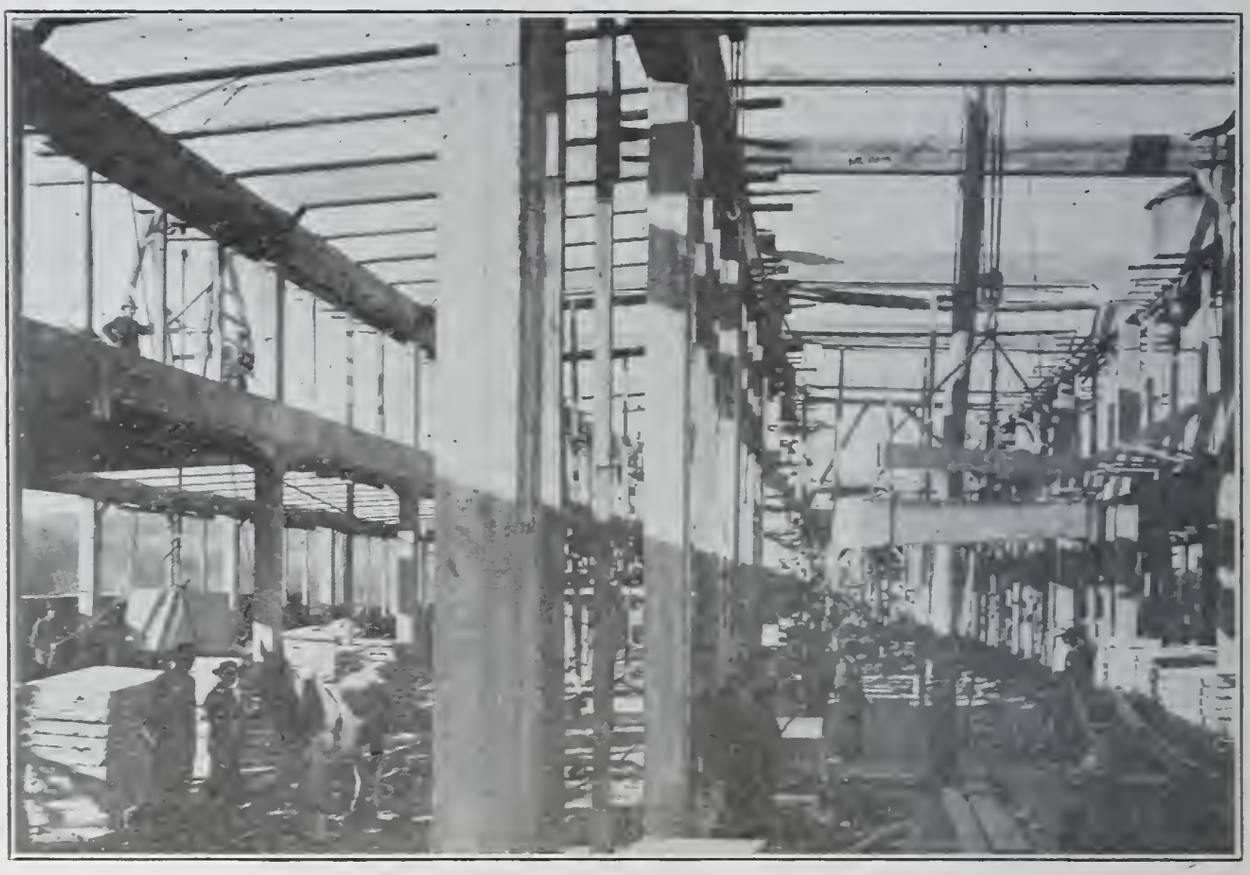

Fig. 6

swung through 90 deg., or parallel to the tracks, and the gantry moved forward until the beam was over the moving-carriage, when it was lowered onto the carriage supports. Two men were used in loading beams.

The carriage used for moving beams was constructed as follows: The bodies of two industrial cars were removed and wooden turntables mounted on the trucks. Two ordinary *T* rails were laid parallel, on top of the turntables, with about 12 in. clear space and secured at each end. Two stirrups were

hung on the *T* rails about 18 ft. apart to carry the beam. See Fig. 7.

The carriage track extended to the near end of the row of beams and was parallel to and midway between the other two tracks on which the gantry traveled.

A horse was used to pull the beams to their respective positions ready for placing. The snatch line was long enough to reach from the mill building to the place of loading so the horse could remain on the earth floor of the mill, this part of the work being done before the concrete floor was laid.

Fig. 7

The dry kiln beams were first erected, all being taken up through the mill and into each division of the kiln as required.

A 35 foot gin pole was used for hoisting the beams, the hoist line being operated from an engine. A bridle similar to that used on the gantry was used to hoist the beams into position. This pole was first erected in each kiln slightly ahead of the position to be occupied by the first beam. The carriage was then

run to the required position near the pole, the bridle chains attached and the beam hoisted into place. As each was set in position the pole was skidded along about six feet on a plank to the required position for the next beam. The beams in each kiln were thus placed with but one erection of the pole. See Fig. 7.

The erection of the beams in the mill building was more difficult on account of the monolithic beams at each column, which necessitated the partial lowering of the gin pole for each bay. Thus only three beams could be erected for each erection of the gin pole. The pole was more easily guyed in this building, however, the lines being attached to the monolithic work.

The Speaker takes pleasure in acknowledging the courtesy of the Executive Committee and officers of the National Casket Company for the privilege of presenting a description of this part of their Asheville plant and wishes to extend his congratulations upon their adoption of the latest and most approved construction for factory buildings.

The plant was designed throughout in monolithic concrete by the well known firm, W. G. Wilkins Company, Engineers and Architects. Upon thorough investigation and approval by them unit-member methods were used for the roof construction and the Speaker feels that generous acknowledgement is due this firm who contributed to the success attained.

DISCUSSION

Mr. W. G. Wilkins: I want to thank Mr. Cummings for the boquets he threw the W. G. Wilkins Co. I might say that the W. G. Wilkins Co. simply designed the building as a monolithic structure. Mr. Cummings was given the contract for the building and it was through his advice that the method of the roof construction was changed from monolithic to unit system. If we had known as much of the secrets of the contractor's end of it, we possibly would not have allowed that change without a reduction in price. The result has proved that it is a very satisfactory method, and I certainly agree with Mr. Cummings that it is a method that should only be used on one story buildings.

The question was asked by President Morse as to why that building of the National Casket Co. was built in South Carolina. The Company has factories for the manufacture of caskets all over the country, one on the North Side, one in Rochester, one in Jersey City, and I don't know how many more, and they conceived the idea that by manufacturing their lumber in the south before it was shipped they would save a great deal of money on freight on the lumber which was brought up and wasted in the manufacturing process. When they first came to us to have the plans prepared they wanted the cheapest possible construction they could get. They had an idea of the ordinary wood frame construction all through. Talking the matter over with some of the officials I discovered how much they expected to save and we persuaded them that it would be economy in the end to build the reinforced concrete buildings instead of frame buildings. I have been told, that they saved in freights the first year, about what the buildings cost.

Mr. Cummings has told us about how unreliable reinforced concrete can sometimes be made in the mixture and the materials used. He has almost made me afraid to build any more concrete buildings higher than one story.

I want to make a criticism of the Author's statement that the engineer of reinforced concrete ought to have been out on the job first. I think he is all wrong there. I have learned something from Mr. Cummings tonight without actually seeing it go through the mill.

There is one question I would like to ask as to what the saving in reinforced concrete construction is over solid concrete construction in a building say eight or nine stories high. Of course with the solid concrete construction we all know the columns would have to be very much larger and would take up considerable of the floor space. I would like to know just how much saving there is in actual cost between the two types.

THE AUTHOR: I do not know that I quite understand the question. I would object to building a seven story building of solid concrete. You would save I would think about 20 percent. The concrete would cut no figure in the cost of the building. It

is the form work. I want to impress the fact that it is the form work that costs.

MR. EDWARD GODFREY: I do not agree with Mr. Cummings in what he says about the necessity for men to engage in the work themselves in order to understand how to carry it on. I do not think it would be necessary for a man to mix concrete to know when concrete is mixed right. I do not believe it would be necessary to place steel rods or to do any of the actual work of construction. I think a great deal more can be learned by going around a job and watching everybody than by engaging in any special part of it as a workman, the way he seemed to infer.

LUMBER

By F. R. Babcock

I hardly know where to begin or leave off, these are the most difficult questions when dealing with a subject we feel we are familiar with. I noticed in a circular received today, a few figures that would perhaps be interesting. This circular indicates the lumber business as being the fourth largest enterprise in the United States. The annual production is about 40 billion board feet valued at from 657 to 750 millions of dollars in a normal year. The private and national forests are estimated to cover about 600 million acres, or 32 percent of the total land area of the United States, exclusive of Alaska. Of this about 194 500 000 acres are in national forests. The lumber industry is the second largest enterprise in the United States as to tonnage, being excelled only by coal. The firm I represent shipped during the month of April, through our Pittsburgh office, 1005 carloads of lumber, aggregating 17 946 558 feet, together with 3 823 550 plasterer's lath, valued at $423 460.57, indicating that the average price of lumber is somewhere from $20 to $25 per thousand feet, taking good, bad, and indifferent.

Twenty-two years ago, when I went to Saginaw to learn the lumber business, that city was one of the distributing centers for white pine lumber. About a year later I came in contact with an experienced lumberman, probably 55 years of age, who felt that the lumber business in this country had so far depreciated that there never would again be a firm that could sell 15 000 000 feet of lumber in a year. Yet compare this with the figure I gave you a little while ago of nearly 20 000 000 feet in a single month.

The first topic assigned me is the source of lumber in the United States. I imagine your Chairman does not wish me

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to go into this thoroughly, because there is a great deal that could be said. We, of the middle west, have never looked upon the New England States as lumber producing territory, largely because they are located so conveniently to one of the best markets in the world which takes all their production. As a matter of fact those states, especially Vermont and New Hampshire, and some parts of Maine and Massachusetts, have been great lumber producing states and are still producing white pine and spruce. The Adirondacks, in upper New York, is still one of the greatest lumber producing sections in the small class of spruce timber. One of the largest timber producing companies in the United States, the Maine Company, is manufacturing spruce lumber. Pennsylvania, as you all know, has been world-renowned as a lumber producing state, and it is a question in my mind whether that part of the state west of the Allegheny mountains has not produced more lumber than any like territory, acre for acre, in any other state in the Union. There is yet probably ten billion feet of lumber in the western part of the state, largely owned by the United States Leather Company. West Virginia has been one of the great producing states during the past ten years. The Carolinas are now producing in the neighborhood of two or three billion feet annually.

In this particular section we are probably more interested in the production of North and South Carolina than that of any other territory by reason of the fact that there is more long leaf yellow pine structural timber shipped into this country from there that never was long leaf, and never bought or sold for long leaf except by some one who has chosen to fool the consumer. Probably more abuses have been practiced with the product of those states than from anywhere else. We have what is called sap pine, commonly known as corn field or field pine, where the corn rows can be seen through the woods now, simply showing that it is second growth timber on soil that was tilled prior to the Civil War, and during the past 45 years that timber has come to be of commercial size. Some of the largest is about two feet in diameter. It is short leaf, or sap pine, of very rapid growth, coarse grained, and is very frequently shipped into Pittsburgh under the guise of long leaf

yellow pine. The abuse is more frequent, however, in substituting what is known as rosemary or original growth short leaf pine. The rosemary pine is a tree very similar to short leaf, a little coarser growth than long leaf and principally all heart. Therefore, in my own practice I have come to feel that a good rosemary timber is practically as good as long leaf. Its tensile strength is not quite equal, but its wearing qualities are just as good. But the trouble is they do not stop there. When you tell them they can ship rosemary they will load up anything they can buy cheap. The result is we do not get much good long leaf timber from this territory, notwithstanding the fact there is just as good long leaf in the Carolinas as in Georgia or any other state. But rosemary and short leaf predominate and you buy long leaf and get the others as a rule. It is well known that all the southern states are really known as the long leaf unbled pine territory, which is supposed to be the best that can be bought. They are great producing states and have a very great acreage. I would not undertake to tell you anything about the amount of yellow pine that is cut. In looking over the figures I have observed that yellow pine constitutes very nearly one-half of the soft lumber that is manufactured in the United States.

When Mr. James first came to this country and settled where Jamestown, N. Y., now is, that was about the head of the oak belt which extends down through the Carolinas, Tennessee and Kentucky. It is all the same character of oak that Mr. James discovered and which led him to build furniture factories in Jamestown. Indiana has been famous for its quality of white oak. It is practically all in one belt and most all of the fine textured oak of the country has been manufactured right out of this middle west by which we are surrounded. In the Alleghany Mountains within ninety miles of Pittsburgh we are cutting oak that goes into New York City, which they consider the finest textured oak they can buy any place.

The Pacific Coast is of course the great source to which this country will eventually have to look for its supply. The Vancouver Islands alone have more timber than this country will consume in the time of any of us, notwithstanding the fact

that many people imagine the timber will all be cut out in the next few years. These theorists have never tramped back in the mountains over thirty or forty miles of the roughest kind of territory to find out what is back there. They take somebody's word for it and consequently do not know anything about it. It may be interesting to know that when we started on the tariff question a year and a half ago, Gifford Pinchot was in favor of free lumber, and whatever he said regarding the forests of this country, President Roosevelt believed, and had a right to, because Pinchot is a conscientious and able man. He labored under the supposition that to take the duty off lumber would bring Canada lumber in and that would conserve our forests. Every thousand feet of lumber that came in from Canada would lessen the destruction of our forests just that much. We spent more time and energy to convince Gifford Pinchot that he was wrong than to convince the Ways and Means Committee that we needed the tariff right where it was, for when we had convinced him our work was practically done. But he would not take our word for it and sent his men to the Pacific Coast and other parts of the country to investigate conditions. Our contention was that if the Canadian lumber came into this country it would only be the lower grades, because their home market consumes the better grades. That would force the price of our lower grades so low that we would be compelled to leave 25 to 55 percent of the lower qualities of logs to decay on the ground, that we now haul 35 or 40 miles to the railroad. And these logs would become a menace, as every log cut and left in the woods, because not good enough to come into the market, is a forest fire feeder, and when the forest fire gets in it kills far more than could be saved. This is especially true in the southern country where the woods are very different from ours. One can drive through the heaviest timber country in Georgia with a team and wagon. It is good pasture and is as level as a floor. But there is so much turpentine in the timber that if care is not taken in burning the discarded material after harvesting the lumber there is danger from forest fires which will kill the live timber. The turpentining of timber down there is now more remunerative than

manufacturing lumber. It will be realized that a great deal of care must be used in raking around and protecting the boxes of those trees so they will not get fired and kill them.

Cypress lumber is being used very largely as a substitute for many higher grades and more expensive finish lumber, and is specified in place of white pine in many instances. But there is not much in the country, being located mostly in swamps, particularly of Louisiana. There is the nearest approach to a lumber trust in cypress than in any other class of lumber manufactured and sold in this country. Fully 65 percent of the cypress output is sold by the Louisiana Red Cypress Company, which is a selling agency that represents something like 35 mills, and in the recent investigation of the socalled lumber trust that is one of the things the government unearthed.

The white pine in this country is very largely cleaned up with the exception of Minnesota and some in Wisconsin. Idaho produces a pretty good quality of white pine, we are getting some in the mountains of Tennessee and there is a small belt in New Mexico that is now being brought into this country.

We pass then to the Pacific Coast where the fir, sugar pine, redwood and red cedar grow, all of which are very excellent lumber. It will not be long until the fir will be the cheapest timber in this country and I am safe in saying it is one of the best structural materials in the way of timber that any country has ever used. It is close grained, its tensile strength is practically that of oak, and there will be plenty of it for years to come.

The second topic assigned me is the proper season to cut the various kinds of timber. This is a question that would raise more difference of opinion between theorists and actual operators than any other in our business. Years ago all the lumber that came into this market came down the Allegheny river in barges. It was cut during the winter when snow was on the ground, hauled to the river bank and floated down in the spring freshets in the log, sawed in portable mills or the saw mills that lined the banks of the streams, and rafted down to the cities. This always occurs in all development, and of course is the best lumber that ever comes out of a territory, that along

the streams. They make it cheaply and it is always sold cheaply.

Years ago many people were lead to believe that lumber was not good that was not cut in winter. As a matter of fact that belief predominates today. My own belief is that after it is cured it does not make a particle of difference whether it was cut in the winter or summer. As we began to get back from the railroads, we began to cut our hard wood and run our mills the year around under the pressure of necessity. The old maple specifications always called for winter cut and end dried, but that is all forgotten. But we do have to make a considerable study of it. Speaking more especially of beech, birch, maple, chestnut, white pine, linn and bass wood, these lumbers are cut in the winter when nature is at rest, when the sap is down, will lie in the woods nearly all summer without damage, and they can cut out of the log most any time. But if one undertakes to cut any of those woods in the summer time the sap will sour and they will begin to sap-rot within 30 days. That is what has brought about the general belief that the lumber will not last after it is cured.

I was not quite sure of my own grounds on this point and I wrote to my brother who replied as follows:

"My experience with the cutting of hardwoods has been that beech, birch, and maple can be cut from the first of October to the first of April if we have a good winter, but for an early spring believe that the middle of March is as late as hardwoods should be cut in order to get the best results from handling them; that is, to prevent staining in the pile and prevent boring. The different kinds of oak can be cut from August until the first of March. In cutting these woods in this season our experience has been that we can hold over in the log from six to eight months through warm weather without damage. The main thing is to cut hardwoods when the sap is down, to prevent decay setting in at once. For instance, if we cut any kind of hardwood along through the middle of April or the first of May it will commence to sap rot in thirty to sixty days time. Basswood, poplar, linn or cucumber cut from October to the first of March should be sawed into lumber within three months after the first of March, as these woods are apt to sap-rot much quicker than the other hardwoods; also cherry, ash, chestnut, chittum and gum, are less apt to sap-rot than the other hardwoods. Holly, from which we gather the leaves and berries for holiday times, is a wood that can be cut any time of the year and will

not shrink, sap-rot, or stain, and will not change its color from exposure to the weather, but will remain white. Experience has taught us that all of the above mentioned hardwoods, with the exception of holly, will last from two to three times as long when exposed to the weather, when they are cut in the extreme months of the years, for when the tree is felled it stops the flow of the sap."

I also wrote to our superintendent down in Tennessee. He modestly replied with five closely written pages to tell me that he did not have much to say. He did touch, however, on one or two questions that are of considerable interest, one more particularly as to a pile of hickory that the worms were literally cutting to pieces, and nobody could account for it, from the fact that the logs were cut in the dead of winter and the lumber was a year old and dry as a bone before any boring began. Had that lumber been cut in the spring or summer every one would have said it was because it was cut when the sap was up. It simply goes to illustrate that the conditions in regard to curing lumber depend very largely upon the curing yard. If there are low damp places in the yard where the lumber lies in a comatose state, for a period of several months, it does not matter how much care is taken in piling and drying the lumber, it is very apt to sour and the worms will destroy it. This is one of the things we have to study in locating a saw mill to get a suitable piling ground of several acres free from damp places because we carry from twelve to fifteen million feet of lumber on the stick all the time, requiring a territory that is level and somewhat similar to a railroad yard with tracks between double rows of piles. One of the things that is imperative in locating a saw mill is to get the piling ground so that the lumber will cure rapidly.

Now I know the trouble with that pile of hickory our superintendent referred to. It is on low, level ground, right at the foot of the mountains, and last year we had two or three months of heavy, damp weather, and while the yard is thoroughly drained, yet we have floods that raise the water up under the lumber piles, and gathering dampness in that lumber caused the boring.

We had a complaint a while ago of some beech lumber that was kiln dried and piled in a shed. When the flooring

was laid there w as a variation of $\frac{3}{16}$ in. in a $2\frac{1}{4}$ in. face. The wholesaler through whom we sold that lumber took the position that it was caused by the lumber gathering dampness. I was considerably annoyed because I did not see how there could possibly be that much variation in strips run through the same planer. We took samples and sent them back to the mill where they were put in a dry kiln and when brought out a few days later they were exactly the same width, demonstrating that the kiln dried flooring gathered dampness enough to swell it to that extent. Hence, this is one of the arguments that a thoroughly air dried flooring is better than a kiln dried flooring. That argument would not satisfy people in a building like this, and for use here we would advocate kiln dried flooring because of the excessive and continuous heat. But if this floor were exposed to dampness for a short time it would buckle up and spoil it, whereas, if it were air dried, dampness would not have that effect on it.

I notice the third subdivision is the curing of lumber, and I feel that I have pretty well covered that in what I have said under the head of the proper season for cutting. Cutting and curing are practically one process. In order to successfully cure lumber proper care must be used in piling it at the time it is cut, due care must be taken to have proper air chambers through the piles, and to pile the lumber with a pitch so that rain will not drift in and run down the pile. We try to give a pile of 16 ft. lumber a pitch of 10 in. or 12 in., and this is one of the hardest things we have to contend with. For some reason in running a pile up 30 ft. it generally runs forward a little which throws the major portion of the weight on the head crosser, the head foundation, and that is one of the things we have to be very careful about. If we put a green hand at it, he will put just as good a foundation under the back part as the front, and as a result when the pile has stood a few months the greater weight in front will make it sink down and the pile tips over.

There is very little attention paid to the curing of lumber other than in the selection of the curing yard and piling the lumber. Down in the southern country where they manufacture

poplar, many people put a thin strip on the ends of every piece of the best grade of poplar to keep it from season checking. That seems like a pretty expensive operation, and the only thing that enables them to do it is that lumber is practically all used for building automobile bodies, and we are shipping today poplar lumber that has an actual market value of about $60 or $70 a thousand to automobile factories at an average of from $135 to $140 a thousand, f. o. b., cars at Cincinnati. It is simply because the demand has brought about an almost unheard of condition. That is a price 25 to 35 percent higher than first class frontier mahogany can be bought for. But it is a class of lumber that is advantageously used in automobile bodies and it is a question of using that or adopting aluminum. One or two far sighted companies have gone into the country and contracted for about 90 percent of all the big poplar that will be produced in the next two years so as to insure their supply. In doing that they have jumped the price on themselves $25 to $50 a thousand, because they knew if they did not do so the price would be raised to a figure even higher.

As to the fourth subdivision, grading, I noted when your Chairman came to see me the other day he was under the impression that the grading of lumber is governed locally and that we had a grade of lumber especially adapted to Pittsburgh. This is very true and is brought about by the condition I outlined when I started in. It is simply because some unscrupulous dealer sells one thing and ships another. Probably Pittsburgh has suffered more than any community because of its peculiar geographical location. We are at a point where there is no distributing yard. Cleveland, for instance, is a border town and lumber is shipped by water from all the Great Lake districts. It is there unloaded, graded and shipped out of that market. This is also true of North Tonawanda, Toledo, Sandusky, Buffalo and Chicago. Pittsburgh does not enjoy that privilege, therefore we do not have anybody that carries a wholesale stock, and consequently the consumer has less opportunity to know what he is getting because he cannot see it beforehand.

I want to close by giving some figures from a statistical report from 8811 mills, which include all the important mills

in the United States. There were manufactured during 1909 a total of 27 820 098 000 feet of lumber, which averaged per mill 3 729 840 feet. You will observe that the majority of this lumber was not cut in very large, up to date mills. We do not consider a mill that cuts less than 25 000 000 feet much of a mill. The increase of 1909 over 1908 was 43.62 percent and a slight increase over the product of 1907. The large increase in 1909 over 1908 was due to the panic, but 1909 actually produced more lumber than 1907, one of the palmiest years the lumber business ever had in this country. In this total there was 23 170 482 000 feet of soft wood as against 4 649 616 000 feet hard wood. I shall attempt to show briefly how this was proportioned among the different classes of woods, and where manufactured.

Yellow pine has first place, with a total of 9 768 577 000 feet including long and short leaf, or 42.23 percent of the total production of soft wood. Fir on the Pacific Coast produced 4 313 494 000 feet and takes second place. White pine comes in third place with 2 222 234 000 feet. Hemlock is fourth, with 2 081 642 000 feet, exclusive of the Pacific Coast hemlock, which aggregated something like 103 000 000 feet. The reason I separate that is because it is called by the same name, but is an entirely different character of hemlock. It is not included in our eastern product.

The state of Washington leads all states in the production of shingles, putting out 7 994 251 000. This is what is known as the red cedar shingle, the only shingle used in this country very largely, though we do get a few red wood and some cypress.

The Pacific Coast product increased 44 percent in the year 1909 over former years and was composed of fir, spruce, redwood, red cedar, sugar pine, larch, white pine and hemlock. It is seen that while the eastern states are working out and depreciating, the Pacific coast is almost doubling every two years and a half.

Virginia, North Carolina and South Carolina furnished during 1907, 2 177 273 000 feet; in 1908, 1 741 993 000; in 1909, 2 260 580 000 feet. It will be observed that in 1908, the panic

year, there was a great falling off. The year 1909 surpassed 1907 by a small percentage, which is really a fair pulse of the situation throughout the United States excepting on the Pacific Coast, where there is a much more rapid development.

DISCUSSION

Mr. T. D. Lynch: I have been exceedingly interested in the talk of Mr. Babcock, but the hour is so late that I feel it would be imposing on the good nature of our members and friends to keep them very much longer. There are a few phases, however, of the lumber situation that I would like very much to speak about. My experience has been more particularly with hard lumber, such as maple, ash, hickory, oak, etc. In looking up this question a few years ago I must confess that I was very much surprised to find how little the average person knows about lumber, and how little even engineers know about the lumber going into their structures.

There are a great number of species of the same kind of lumber, and these vary widely in their qualities, depending on local conditions. For example, there are eight different species of the pine family, thirty-six of the oak, six of the ash and eight of the hickory family. The location, and whether the timber is cut from the hillside or from the valley, makes a great deal of difference in the quality of the material so grown. Take for example the hickory family: This is divided into eight species, as above noted, and into two general groups; viz., the pecan group and the true hickory group. In the pecan group there are four species: The pecan, which is a southern growth and produces brittle lumber; the water-hickory, a small southern tree of very inferior wood, known locally as the "bitter pecan"; the nutmeg hickory, also a southern growth, producing timber of very little value, known locally as the "pignut"; and the pignut hickory, found in the north, a very brash wood.

Of the group of true hickories there are also four species: shagbark, known locally as the "shellbark," producing a hard-shell nut, growing generally through the central part of the United States. It has a shaggy bark, grows tall and slender, and produces a good, tough lumber; the kingnut, a big butted shell-

bark, grown in the Ohio and Mississippi valleys, and makes a fairly good lumber; the black hickory, a tight bark hickory producing a smooth nut having a round, thin shell, known locally as the "pignut," which grows in Tennessee, Kentucky, West Virginia, and Ohio; and the mockernut, a white hickory whose bark is smooth and never scaly, it is of southern growth, and is a fair wood with very good toughness for a southern hickory.

I have noted these few details in connection with the hickory family to show how extensive this question is and how unreliable it is to simply buy "hickory." If an order is placed for "hickory," without any other modifying qualities, we may get any of the eight species named, and perhaps something that is very unsuitable for the work for which it is intended. Even among parties who are familiar with hickory, it is surprising how few are capable of selecting a piece that is tough. I have samples here that show some of these differences. One piece of wood shows a very close grain, unusually light in color, tough and strong. Another piece appears from a casual examination to be quite similar, yet on a closer examination is found to be more or less open grain, spongy, and when physical tests were made it was found to be brash and unreliable. These two samples were grown on the same farm, one on a hillside, giving the tough growth, the other in a marshy bottom nearby, producing the brash material. The tough material has a strength of from 18 000 to 20 000 lb. per sq. in., while the brash material has a tensile strength of 7000 to 8000 lb. per sq. in., and the former will stand bending while the latter will stand practically no bending whatever.

In the testing of wood for its physical qualities the question arises how to best prepare the sample so that the results will show the true breaking strength of the material in tension, and not show simply the crushing strength or shearing strength, i. e., the ends must be so prepared that the chucks holding the sample will not cause breaking in the jaws of the machine, or of the holding device, but in the part between. A standard sample has been adopted by us being ¾ in. diameter in the middle portion, 1 in. straight length, and the two ends beveled into a cone which takes a specially designed chuck or holder. This cone

shape is so made that the larger part of the cone, near the end of the stick, comes into compression sooner than the part toward the middle of the piece, in order to obviate any crushing of the fibre to cause a breakage at the jaw. We have found this method very satisfactory and worthy of consideration by those who may have such tests to make.

These are points that come to us as users, and it is of vital importance for us to know the source of this material, where it is raised, cured, etc., in order to know to a certainty what the wood is good for as regards its strength and durability.

Another question that is of great importance in reference to lumber is that of curing. Some of our lumber is to be treated, and it is important that it should not shrink. In order to get lumber dry it is sometimes necessary to kiln dry it, and that in itself is a very interesting question. A few years ago we had occasion to remodel our dry kilns, and we desired to find the most modern way of handling the lumber and operating the kilns. In order to determine these points we visited some of the largest users of lumber, and to our surprise not a single one of them could advise us in detail how they dried their lumber, how they operated their kilns, what temperature and time, including the humidity, were used at the various stages of the drying. These manufacturers had men on the work who had been with them and grown up with the work, and were able to do it in a satisfactory manner, but could not tell how it was done. They were willing, however, to demonstrate these points, and the only way that seemed available for obtaining this information was taken, viz: To stay on the work long enough to see it done and take such notes as might be necessary to carry it out later on. These points are brought out to show how hard it is to get at some questions regarding lumber, and what it means to be able to obtain definite qualities of lumber, the material about which we have all known and worked with through all our years of experience.

In treating lumber where it is necessary to remove all of the moisture, we have found it practicable to use lumber containing moisture not to exceed 10 percent, whereas if the moisture does exceed this amount there will be checking, spoiling the

lumber during the treating operation. Samples are herewith exhibited showing lumber which has been impregnated and which contained 16 percent moisture, the large crack through the center of the piece is the inevitable result, whereas the other piece herewith exhibited shows a similar size stick that had less than 10 percent of moisture, and the wood is entirely homogeneous, solid, and no shrinkage strains are in evidence, which shows the direct effect of moisture in excess of 10 percent.

Another question that may be of interest to the members of the Society is that of shrinkage. The shrinkage of wood in the lengthwise direction of the stick of timber is practically zero, while the shrinkage around the rings may be a certain amount, say ⅛ in., ¼ in., or even ½ in. to the foot, whereas, across the rings in the radical direction, the shrinkage from outside to center will not exceed one-half the above in the direction of the rings. So when a log is cut, the shrinkage of different pieces in the same log will be different with reference to whether the lumber has been cut across or lengthwise the rings in the log.

MR. F. W. WINTER: I would like to ask what effect the boxing of long leaf yellow pine has on the quality of the timber.

THE AUTHOR: Its market value is not affected. By the process of boxing timber we produce what is known in this country as tapped lumber. That is more particularly shown in our rift pine flooring. Three times its normal weight is produced by boxing the timber, which congregates the pitch in the butt of the log, therefore that log has to be butted off or you are going to reduce the grade in a certain amount of timber. Of course by boxing timber you lose perhaps 10 percent by killing the trees unless you are so situated as to be able to go through the woods and take out the trees as they die. Yellow pine is very susceptible to damp rot and you lose at least 30 percent of the timber that lies in the woods.

MR. E. K. MORSE: Would you care to express yourself as to the duty of the government toward reforestration?

THE AUTHOR: My view of reforestration is that it is the duty of the government to first institute it and that would nat-

urally force the timber owners to follow suit. But there has been nothing so far to show that timber can be reproduced at a profit under present market conditions. I believe that laws can be passed that will make the lumber manufacturers preserve the young timber. This was one of our fights before the Inter State Commerce Commission. The Master Car Builder's rules provide that stakes must be furnished 3 in. by 4 in., and 4 in. by 5 in., good, sound, hard wood or saplings. Staking a carload of lumber requires 6 stakes on each side, which means 12 thrifty, young trees, anywhere from 3½ to 5½ in. in diameter, for each car, to furnish part of the equipment that belongs to the carrier pure and simple and is now imposed upon the manufacturer and shipper. This has been practiced until it has become a custom which Chairman Knapp of the Inter State Commerce Commission can see no reason why they should change. It has been done for 50 years on the same basis. In other words a custom that has been indulged in for years, becomes a law right or wrong.

Mr. A. Stucki: In regard to the question of drying timber and especially referring to the piece which cracked during the process, I understood Mr. Lynch to say that timber containing not over 10 percent of moisture will not crack, but with 16 percent, it will do so. Is this not simply a question of how slowly you dry this timber? In other words it looks as though by choosing a low enough temperature and a slow exchange of air, the rate of drying can be regulated in such a way that timber of any moisture can be dried without cracking.

Mr. T. D. Lynch: We have been able to kiln dry lumber that has contained as high as 55 percent moisture when it was placed in the dry kiln, and do it thoroughly, without cracking the lumber. In doing this it was necessary to steam the lumber at the beginning of the operation until the lumber was thoroughly heated through and through, bringing the humidity of course to 100 percent. The lumber must be held at this temperature for a short length of time, until thoroughly saturated with moisture and thoroughly heated, after which the temperature may be gradually raised to 130 deg. cent. and the moisture cor-

respondingly reduced until the lumber is dry. It is preferable not to run the temperature above 120 deg. cent., if proper time can be allowed for the drying at this temperature, although we have had good results as high as 130 deg. cent., as above noted. We have found ordinarily that it requires approximately two weeks for each inch of thickness of lumber to properly kiln dry it, when the lumber at the initiative does not exceed, say 40 per-cent moisture, and we have found that it is not practicable to hasten this time very much and still obtain good results.

MR. E. K. MORSE: Have you had any experience with second growth timber as compared with first growth quality?

THE AUTHOR: Second growth timber is not as good. Second growth forest is liable to grow up and branch out and have limbs that die off as the tree grows up and that makes imperfections in the lumber. From second growth, manufactured in this country, we get no clear lumber, with the exception of what we call sap pine in North Carolina. We do get a certain percentage of that but it is very small. The preponderance is No. 3 and 4. Second growth hickory is considered superior for manufacturing purposes.

As to kiln drying, in the extreme south the yellow pine is of such nature that unless it is kiln dried immediately, the sap will turn black over night, which spoils the grade of flooring. Therefore, all the yellow pine manufactured in the south for flooring, ceiling and finish, goes directly from the saw into the dry kilns, and they are kiln dried in three days time without any damage to the lumber. This would be a physical impossibility with the kind of lumber you are talking about. Oak gives more trouble in kiln drying than any other kind of wood. If the temperature is allowed to go down after the lumber is steamed and start off at low temperature, it will spoil every time.

AIR CONDITIONING APPARATUS

ITS CONSTRUCTION AND APPLICATION

By W. H. Carrier*

The positive control of atmospheric conditions within enclosures is an art of compartively recent development. The conditions for which regulation is sought, are: First, Cleanliness; second, Temperature; third, Moisture or humidity.

The demand for the mechanical regulation of these features has developed rapidly within the past five years, and covers a remarkably broad field of application. With the ever increasing polution of the air in our cities some practical means of air purifying has become essential in public buildings, hospitals, stores, offices, schools, dwellings, and many manufactories.

The hygienic benefits of a uniform and proper degree of humidity, temperature and cleanliness combined with ventilation is now beginning to receive the serious consideration which its importance demands. The irritation caused by breathing excessively dust laden air, even though otherwise pure, is responsible for a large class of diseases of the respiratory organs. Moreover, the spores of contagious diseases are said to be conveyed entirely by attachment to dust particles floating in the air, making dusty air a double menace to health.

Aside from the hygienic aspect the process requirements in many manufactories make air conditioning highly advantageous, or even imperative. This is true in the manufacture of textiles, of photographic films, of all gelatine products, of various confections, in lithograph printing, in the malting of grain, in cold storage of many products, and even of highest importance in the smelting of iron ore. Moreover, it is safe to predict that it will be a short time only before an air conditioning

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*Chief Engineer, Carrier Air Conditioning Co., New York.

installation will be required by law in every coal mine throughout the country as the only sure and practicable means of preventing mine explosions due to dryness of the air in the mines in the winter months.

TYPES OF APPARATUS

Air purifiers are either of the dry air filter type, or of the moist washer type. The dry air filter has its legitimate field and is applicable wherever air is required to be cleaned without moistening. Properly designed it can be made a fairnarily employed, however, in the form of cheese cloth screens, ly efficient means of removing solid impurities. As it is ordior bags, of one thickness, it is very inefficient and hardly worth the trouble of installing. In most cases no adequate means of cleaning is provided and the screen becomes only a hindrance and a detriment to the ventilating system. To make this type effective, three elements are essential:

First, Some mechanical means of continuous, or intermittent cleaning, which will not interfere with its operation.

Second, Cloth, closely woven, or else several thickness of coarse mesh to obtain adequate cleaning, the ordinary cheese cloth in single thickness, will not answer.

Third, Sufficient filtering area to avoid excessive resistance to the passage of air.

The second type of purifier, the air washer, has so many advantages over the dry filter for most purposes, that it has practically displaced the latter type. The usual form of washer depends for its action upon bringing the air into more or less intimate contact with water first in the form of a spray, and second in the form of a film on metal plates. The advantages of the air washer over the dry filter are: That it is compact; it is practically self cleaning; it not only removes solid matter efficiently, but also extracts a large proportion of the soluble gases, such as sulphur dioxide, carbon dioxide, and offensive odors. That the latter may be removed most completely has been demonstrated by installations in the vicinity of rendering works and packing houses, where the air outside would be nauseating while in buildings ventilated with washed air the

odor could not be detected. In such locations, of course, the water must be continuously changed otherwise it would become saturated and ill smelling.

In the early attempts to wash air a coke screen was employed over which running water was allowed to trickle. This device proved very unsatisfactory because it either occupied too much space, or offered too great a resistance, and also it fouled with impurities very quickly, becoming ill smelling and a source of

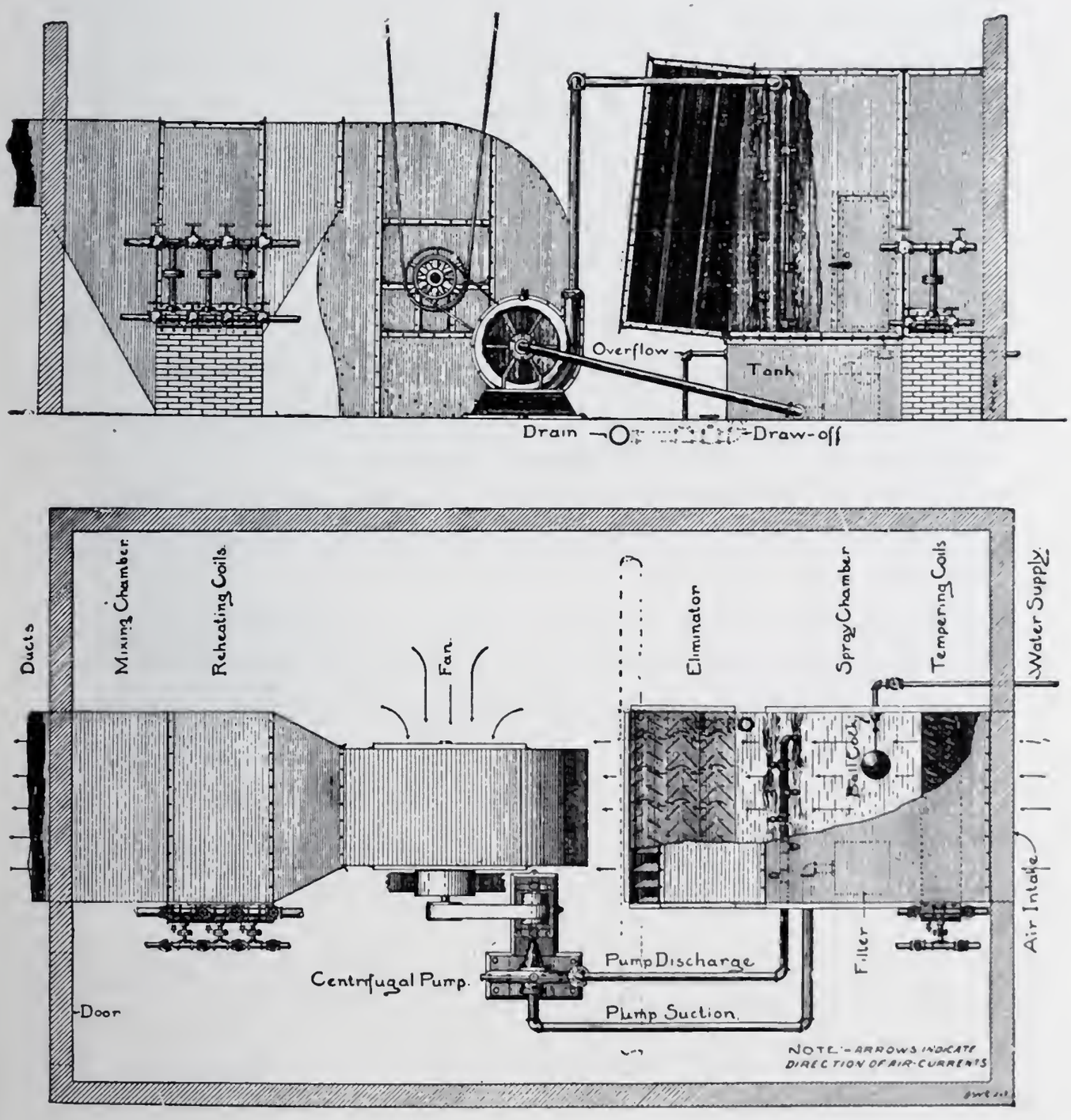

Fig. 1

contamination. These difficulties soon led to its abandonment and to the adoption of the present types of air washers.

All mechanical washers have the following essential features:

First, A spray system for supplying the water, usually requiring some form of nozzle.

Second, A centrifugal pump for supplying the water under head.

Third, A washing chamber in which the air is brought in contact with the water spray.

Fourth, An eliminator for the removal of the water from the air.

Fifth, A settling tank for holding the supply of water which is recirculated.

Sixth, A strainer or filter for preventing the coarser dirt from entering the spray system.

The several makes of washers differ largely in the construction of the spray nozzles, and in the design of the eliminator, the two most essential elements. The following are some distinguishing features of well known washers:

The washer shown in Fig. 1, has an eliminator composed of four rows of separate vertical plates or baffles. The baffle plates are about six inches wide and spaced about six inches apart in the row. Each baffle is provided with a projection or lip for retaining the water which impinges on the plate. The baffles in one plate are staggered with reference to, and placed at right angles to the baffles in the next row. The nozzles, shown in Fig. 2, discharge the water in the form of a vertical sheet which is afterwards broken up into drops by the impact of the air current. The nozzles are cleaned by a hand operated flushing device.

The washer shown in Fig. 3. is particularly distinguished from other types by its *S* shaped spray chamber which forces the air to pass through three sets of sprays. This causes it to occupy somewhat greater space than other types in order to avoid excessive resistance.

The washer shown in Fig. 4, employs horizontal instead of vertical baffle plates. It also differs from all others in using a single spray head at the top of the washer which discharges downwards giving a "spray and rain effect."

Fig. 2

The washer shown in Figs. 5 and 6, has horizontal baffles in the eliminator similar to the washer shown in Fig. 4, but uses nozzles similar in type to those shown in Fig. 1. However, in the washer shown in Figs. 5 and 6, these nozzles are provided with a patented automatic cleaning device.

The washer and humidifier shown in Figs. 7 and 8, differ from others in several features. In the spray nozzle, shown in Figs. 9 and 10, used in this device, the water enters a small cir-

cular chamber tangentially, which gives it a whirling or centrifugal action. The outlet or discharge opening is in the axis of rotation, and is placed at the end of a conical approach. This greatly increases the whirling speed of the water at the point of discharge, and delivers it as a minutely divided or atomized spray that offers an enormous amount of surface for evaporation and cleaning. The construction of this nozzle is such that it is very difficult to clog it with foreign material, as the smallest opening is 3/32 of an inch in diameter, while all the water must pass through two copper strainers, which are 24 mesh. In some washers means are provided for removing dirt from the nozzle while in this washer means are provided which prevents its entrance.

The eliminators in the washer shown in Figs. 7 and 8, are usually constructed of galvanized iron, but may be of copper, and are placed in a vertical position across the discharge end of the spray chamber. Each eliminator plate is made of a single sheet so stamped as to form several corrugations, three of which have projecting lips. See Fig. 11. The plates are held together with galvanized angles at the top and bottom and at intervals throughout the height, so as to keep them evenly spaced.

The action of the eliminator in this washer is two fold. The first portion of the eliminator is designed especially for washing effect and is not provided with gutters so that the water is permitted to pass from one corrugation to the next without obstruction. The second portion is provided with projecting lips to form gutters which complete the elimination of moisture. The plates are spaced slightly over an inch apart, thus subdividing the air very completely and affording an enormous washing surface. The free moisture together with the moisture laden dirt is removed in the eliminator by the combined action of centrifugal force and impact. A distinguishing feature employed in this washer, is the row of flushing sprays placed at the top of the eliminators which continually floods the entire eliminator surface. This greatly increases the effectiveness of the washing surface and prevents the plates from becoming foul.

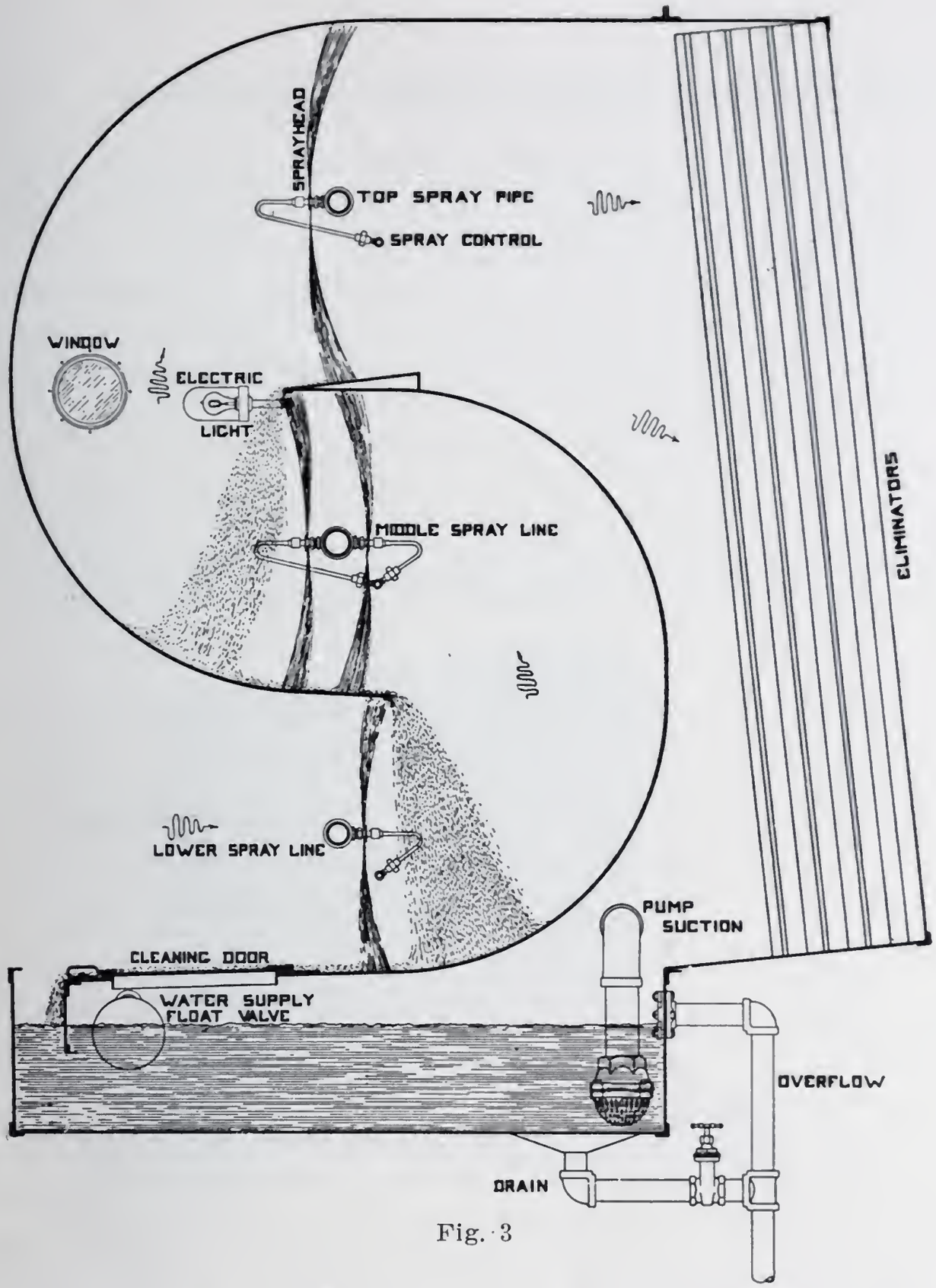
SPRAYHEAD
TOP SPRAY PIPE
SPRAY CONTROL
WINDOW
ELECTRIC
LIGHT
MIDDLE SPRAY LINE
ELIMINATORS
LOWER SPRAY LINE
PUMP
SUCTION
CLEANING DOOR
WATER SUPPLY
FLOAT VALVE
OVERFLOW
DRAIN

Fig. 3

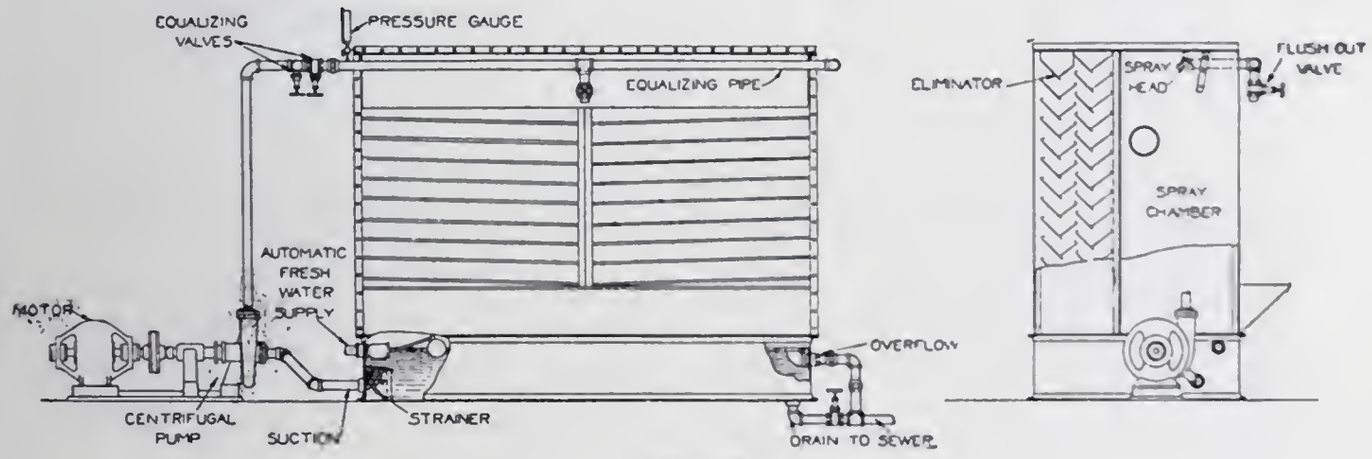
EQUALIZING
VALVES
PRESSURE GAUGE
EQUALIZING PIPE
ELIMINATOR
SPRAY
HEAD
FLUSH OUT
VALVE
SPRAY
CHAMBER
AUTOMATIC
FRESH
WATER
SUPPLY
MOTOR
OVERFLOW
CENTRIFUGAL
PUMP
SUCTION
STRAINER
DRAIN TO SEWER

Fig. 4

The above types of air washers will all do a certain amount of humidifying depending on the degree of contact of the air with the water; none of them, however, as ordinarily used as washers, will give complete saturation. Likewise, they will not give the full cooling action theretically available. Before discussing this feature more in detail it will be well to consider the underlying principles involved in air moistenng.

THEORY OF HUMIDIFYING

It is a well known principle in physics that the vapor pressure or tension of a confined liquid increases with its temperature according to a definite mathematical law. It is also known

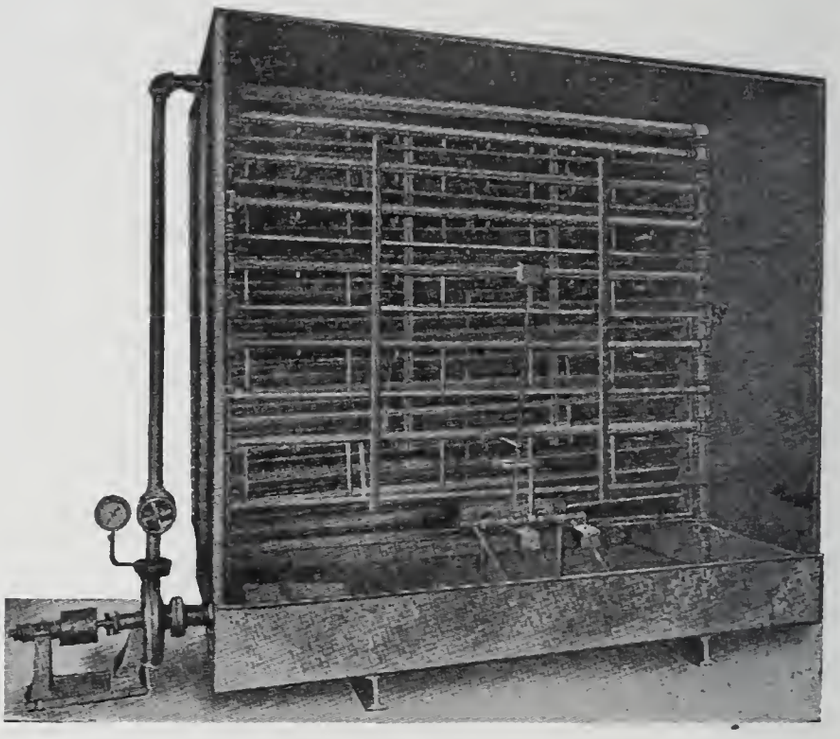

Fig. 5

that a volatile liquid will vaporize in air at any temperature at atmospheric pressure, and that the maximum density of this gaseous product will depend entirely on the temperature regardless of the presence of other gases or vapors. In passing from a liquid to a gaseous state a great amount of heat is absorbed. In general the heat of vaporization is greater the lower the temperature.

The phenomena of water vapor in the air, or humidity, clearly illustrates this. In Fig. 12 the upper curve shows the density of saturated water vapor in grains per cu. ft., at diff-

erent temperatures. It will be noticed that the density, or moisture holding capacity, increases at a far more rapid rate than the temperature: thus starting at 30 deg. fahr. the first temperature rise of 10 deg. gives an increase of 0.9 grains moisture per cu. ft., the second rise of 10 degrees gives an increase of 1.27 grains, the third 1.70, the fourth 2.18, etc. The actual weight of water vapor per cu. ft., is termed the absolute humidity and the saturation temperature, corresponding to this density, is called the dew point.

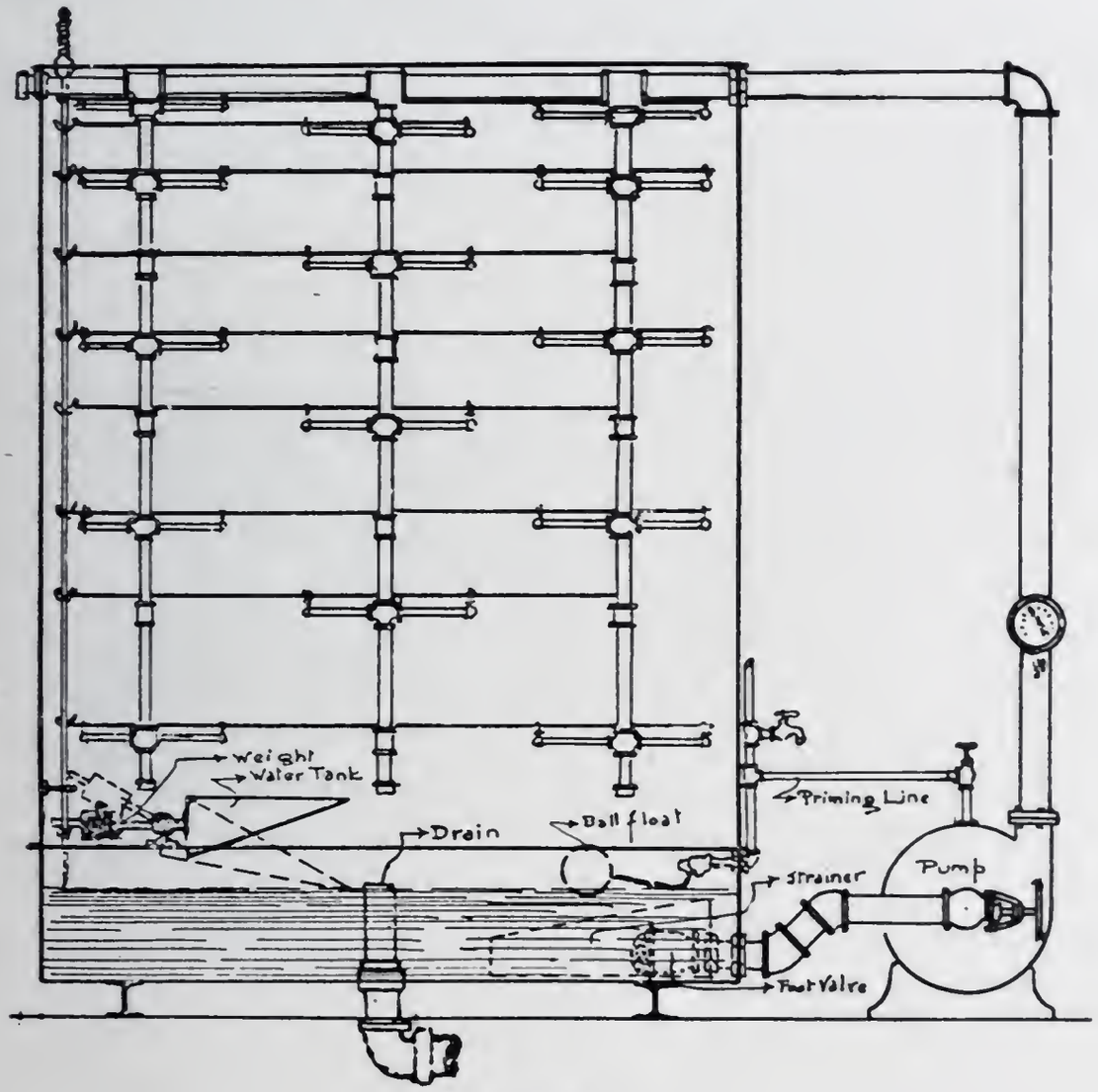

Fig. 6

When saturated water vapor either alone or in admixture with air is raised in temperature without additional evaporation of water, it becomes superheated. This degree of superheat determines what is known as the relative humidity of the air. The relative humidity is expressed as a ratio of actual vapor density to the density of saturated vapor at the same

temperature; i. e., it is the ratio of what the air does hold to what it could hold at the same temperature. When a superheated vapor is brought into contact with a liquid it immediately loses its superheat, partially through evaporation and partially by increase of vapor pressure. In dry air, which is merely a mixture of air and superheated water vapor, the heat of vaporization is taken from the air, from the superheated vapor and from the water itself. When the saturation is completed the air and the water will be at the same temperature, which is obviously between the initial temperature and the dew point. It may be demonstrated that water exposed to dry air and unaffected by any source of heat will remain at a constant temperature as it evaporates, which is considerably below the temperature of the air. This temperature is the same as that which the air will attain when it becomes saturated; this is known as the wet bulb temperature, observed by covering a thermometer bulb with a wet cloth. The difference between this wet bulb temperature and the actual temperature is called the wet bulb depression. This is a direct measure of the moisture absorbing capacity of the air. For each degree depression of the wet bulb temperature a pound of air has capacity to absorb 1.4 grains of moisture. Knowing the number of grains of moisture air will absorb and the final temperature after absorption, it is possible to determine by mathematical calculation the number of grains the air contains at any temperature and wet bulb depression, also to determine the percentage of saturation.

The above theory applies in a very interesting way to the practical operation of air washers and humidifiers, and to humidity control. The cooling effect of all washers and humidifiers when the water is recirculated is due solely to evaporation and is always in exact proportion to the wet bulb depression of the air entering. In a humidifier which has full saturating efficiency the air is cooled exactly to the wet bulb temperature, while in the ordinary washers the air is cooled only from 60 to 85 percent of the wet bulb depression, depending on the intimacy of contact between the water and the air. The spray water always remains at the wet bulb temperature, and the wet bulb temperature of the air remains constant regardless

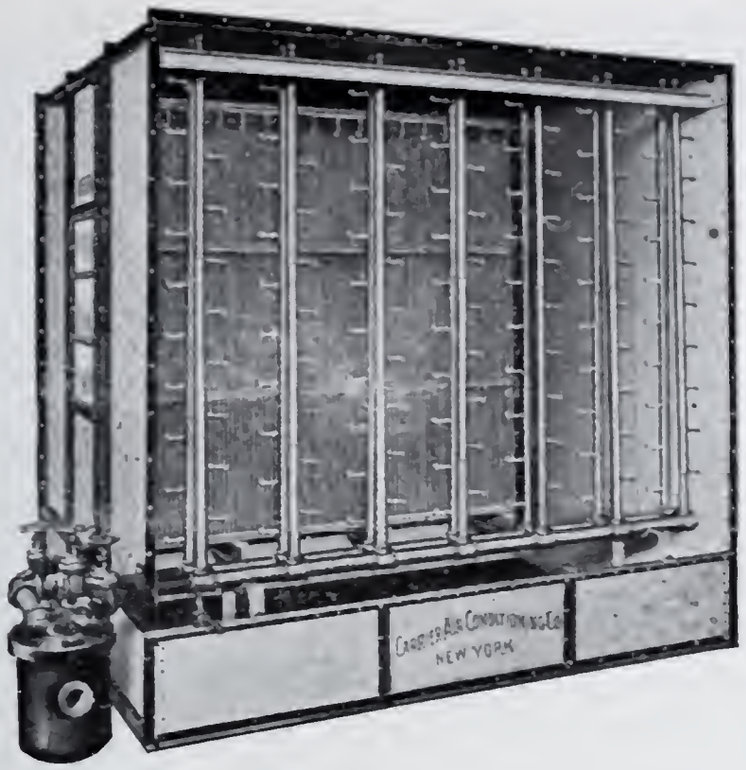

Fig. 7

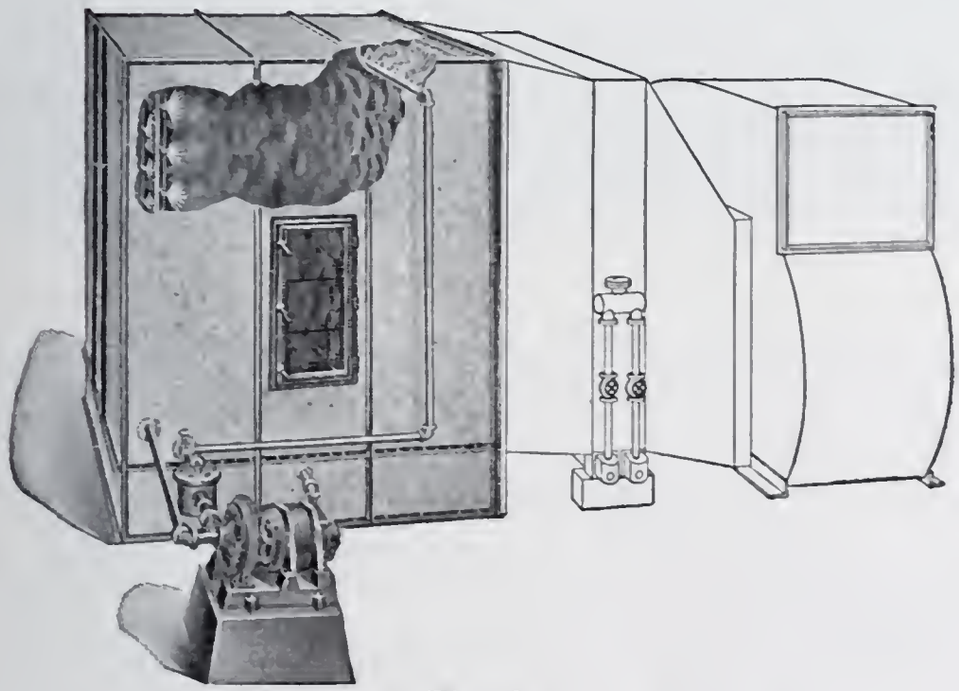

Fig. 8

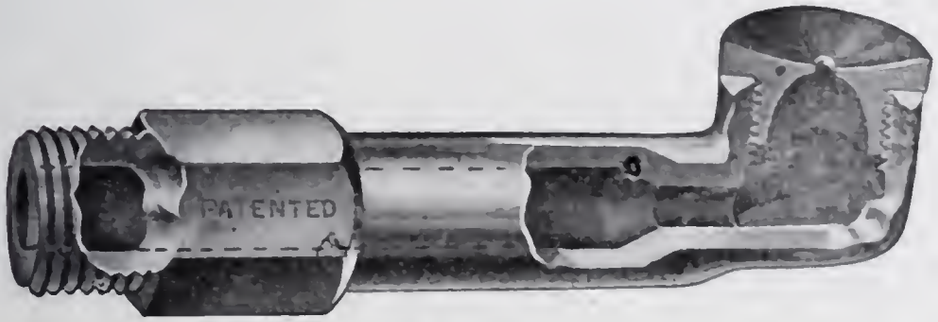

Fig. 9

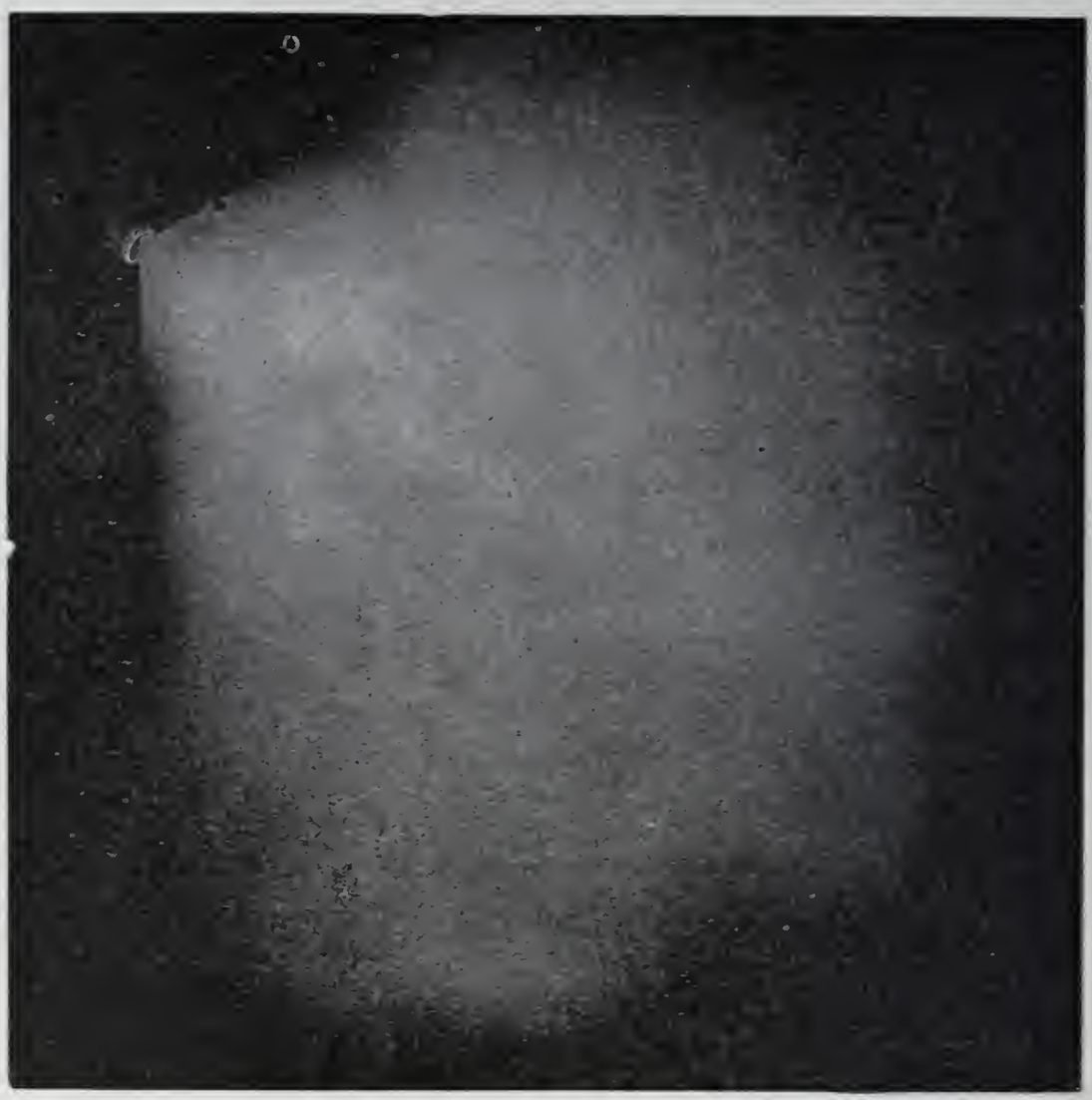

Fig. 10

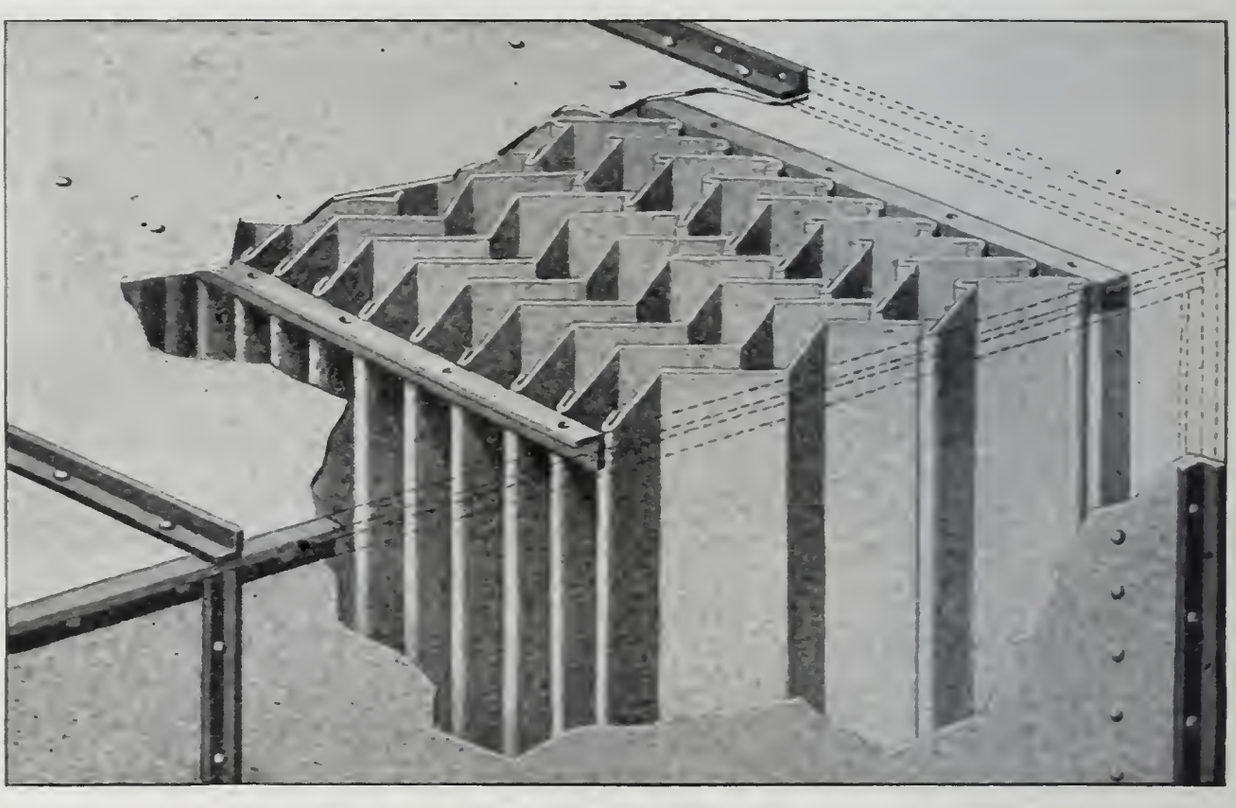

Fig. 11

of the degree of saturation so long as no heat is added or subtracted. This effect is diagramatically shown in the chart, Fig. 13. The curved lines correspond to percentages of humidity, the nearly straight and parallel lines show wet bulb temperatures, and, therefore, indicate approximately change in moisture content under adiabatic conditions. In order to cool without the addition of any moisture the water used in the washer must be somewhat below the dew point of the incoming air. By carrying the temperature still lower and increasing the amount of water the washer may be used as a dehumidifier. There is one installation of these washers where air taken out of doors is delivered uniformly with a moisture content of 2.8 grains per cu. ft. the year around, although the moisture content of entering air varies from ½ grain to 9 grains per cu. ft. The effect of the washer in reducing humidity is similar to that of the jet condenser. The eliminator plates remove the condensed moisture effectively.

HUMIDITY CONTROL

Humidity may be controlled in three distinct ways:

First, By use of some hygroscopic substance as wool, hair or silk.

Second, By the use of a differential thermostat having two elements, one subjected to wet bulb temperature and the other to the dry bulb temperature.

Third, By controlling the absolute humidity, or dew point, with reference to the room temperature.

The first method is too unreliable to be of much value in accurate work. The second method of control can be made exceedingly accurate and is well adapted to regulating where there is a change in absolute humidity in the room to be conditioned. An instrument operating on this principle is shown in Fig. 13. Its essential elements are two rods of hard rubber attached to a frame. These rods are arranged horizontally one above the other and the lower one is covered with a cloth which dips in a reservoir of water. This cloth serves as a wick and keeps the rod continually moist. These two expansible rods operate conjointly through a series of levers upon an air valve. In order

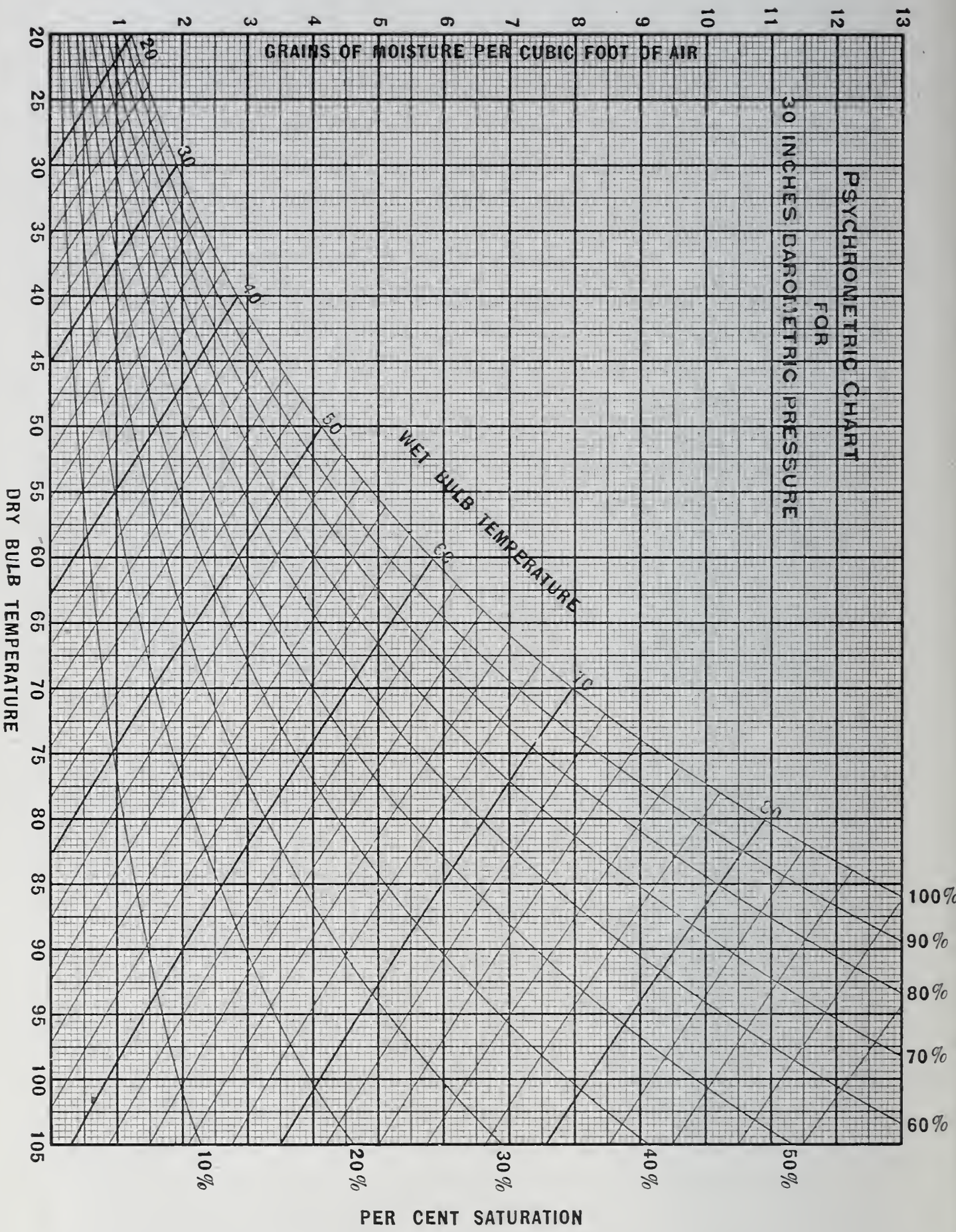
PSYCHROMETRIC CHART
FOR
30 INCHES BAROMETRIC PRESSURE
GRAINS OF MOISTURE PER CUBIC FOOT OF AIR
1 2 3 4 5 6 7 8 9 10 11 12 13
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105
DRY BULB TEMPERATURE
WET BULB TEMPERATURE
10 20 30 40 50
10% 20% 30% 40% 50%
100% 90% 80% 70% 60%
PER CENT SATURATION

Fig. 12

that this instrument shall operate to maintain a constant percentage of humidity over a range of temperature it is essential that it shall produce no movement of the air valve so long as the humidity is constant. These two rods expand in opposite directions to each other and the dry element is provided with an adjustable leverage so that any desired ratio of action may be secured. For example: In order to maintain 50 percent humidity the expansion caused by 8 degrees rise in the wet bulb temperature must have the same effect as the expansion caused by 1 degree rise of temperature in the dry element.

Where the absolute humidity is but slightly affected by local conditions, the third form of regulating device is used. The simplest form of this control is that employed in public buildings for winter use. Here the air is saturated, delivered to the room where a higher fixed temperature is maintained than the fixed temperature at the air washer, and then by varying either temperature and keeping the other constant any desired percentage of humidity may be obtained. For example: If we maintained a saturated temperature of 50 deg. at the apparatus and 70 deg. in the room we will have a relative humidity of 50 percent; if we lower the dew point at the apparatus to 40 deg. and still hold the room temperature at 70 deg. we will have 34 percent of humidity in the room as the result. On the other hand if we have a dew point at the apparatus of 61 deg. and maintain one room at 70 deg. another at 75 deg. and a third at 80 deg. we would have 75, 64 and 55 percent of humidity in these rooms respectively.

An apparatus of this nature is used in the Central District & Printing Telegraph Company's building in Pittsburgh, and is shown in Fig. 14. In this installation the air is tempered by direct contact with a heated water spray. The temperature of the spray is so controlled by means of a thermostat as to maintain a constant air temperature past the eliminator plates. The temperature of saturation is ordinarily maintained at 40 deg. The air is then drawn through the fan, passed through the tempering coils, and forced into the building. This method of fixed dew point regulation is only adaptable for winter use and is employed chiefly in public buildings.

In textile mills it is impossible to maintain a uniform temperature throughout the summer. Therefore, it becomes necessary to vary the temperature of the dew point as the room temperature varies. By referring to the chart it may be shown that the difference between the dew point and the room temperatur is practically constant over a considerable range. This fact is taken advantage of in the control of humidity by means of a differential thermostat. This maintains a constant differ-

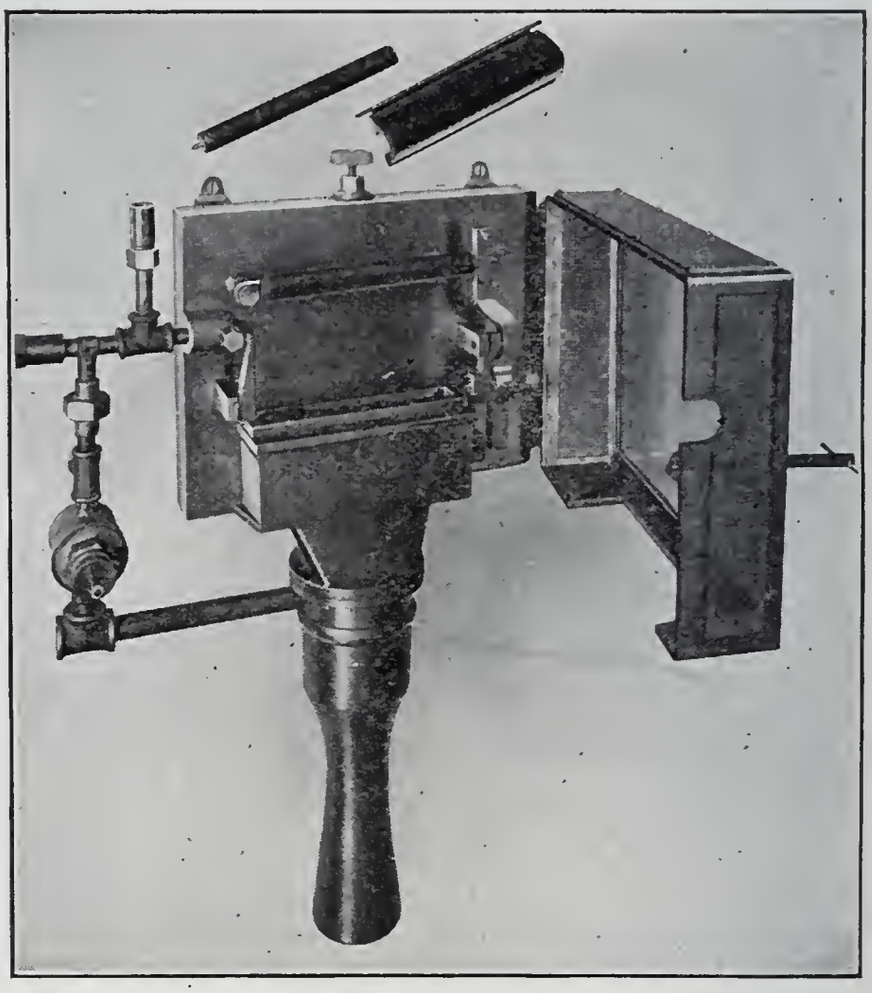

Fig. 13

ence between the dew point and the temperature of the room and thereby regulates the humidity regardless of the room temperature. Two forms of this differential thermostat are used, the form shown in Fig. 15 is used wherever there is but one room in which the conditions are controlled. This thermostat is placed at the apparatus directly back of the eliminator plates and is subjected to the current of saturated air. The thermostat is composed of two concentric tubes separated from each other by means of an insulated tube which serves as an air duct

also. The outer tube is subjected to the current of the saturated air while the inner tube is affected by temperature of the room air which is drawn through the insulating tube. The room air may be conveyed a considerable distance without noticeable alteration in temperature owing to the use of special insulation. The two tubes are connected at their lower ends while the free end of the smaller tube acts upon a pilot air valve. Since both

Fig. 14

of these tubes are made of the same expansive material it is evident that the rise of one degree in the outer element will be entirely off set by the corresponding rise in the inner element, while each temperature variation between the inner element and the outer element will produce a corresponding action on the air valve. If the room temperature rises the inner tube expands, presses on the valve and releases the air pressure. This allows the steam valve on the water heater to open, and raises the

temperature of the dew point correspondingly. Conversely, if the room temperature lowers, the air pressure is increased on the valve which causes it to shut off the steam to the spray heater, thereby reducing the saturation temperature.

Where several rooms are to be controlled from one central plant, a different system is used. In such cases the temperature of the saturated air at the apparatus is governed in cool weather only by means of the ordinary thermostat, thus preventing it from going below a certain specified temperature. Each individual room is controlled with reference to this humidifier temperature by means of a differential thermostat which operates upon the heaters and upon air dampers in the outlets to the room. In this case an air differential thermostat is employed, one element being an air bulb placed at the apparatus in the current of saturated air. Each differential thermostat has a lever operated by two aneroid diaphragms in opposition. One of these is connected to the dew point element by a hollow wire tubing. The other diaphragm is connected to an air bulb of adjustable capacity placed in the room. The pressures in these diaphragms are opposed to each other by means of a lever so that a change of one degree of temperature in one element exactly counteracts one degree change in the other. This lever operates an air valve which controls the air supply dampers in the room by means of an air motor, and the radiation by means of diaphragm valves. This system of humidity and temperature control has been very successfully applied to a large number of textile mills. The advantage of this system is that it gives uniform humidity throughout the year and it permits the lowering of temperature in the mills several degrees in the summer time.

Another field in which air conditioning must sooner or later be generally adopted is coal mining. The numerous and disastrous explosions that have occurred during the past winter are sufficient evidence that further precautions should be taken. To say that three-fourths of these could have been prevented by proper conditioning of the air supply in the mine is no exaggeration. This, as statistics will confirm, would have saved hundreds of lives and millions of dollars. A large part of these

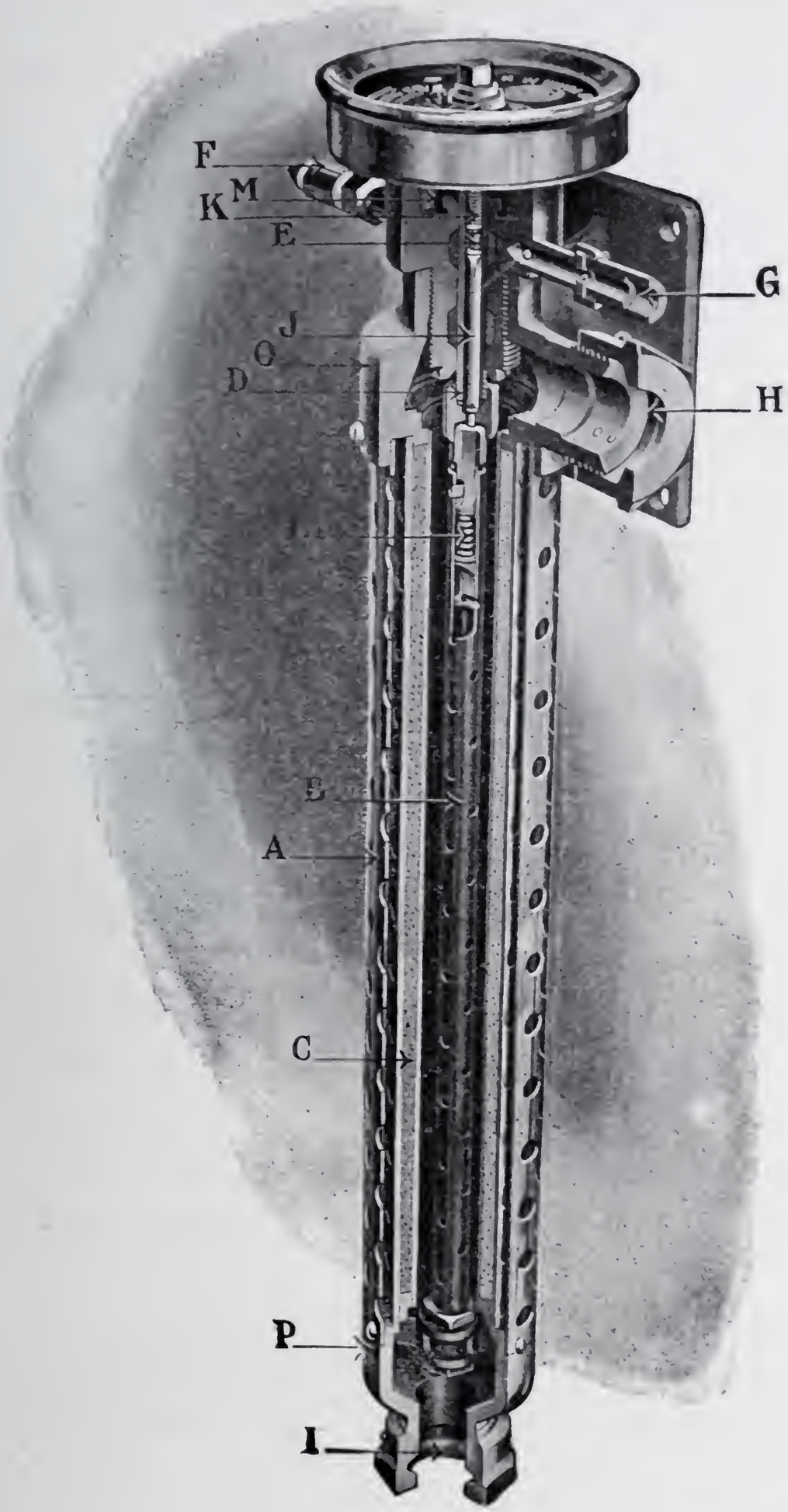

Fig. 15

mine explosions were caused, or augmented by dust, which accumulated owing to the dryness of the mines.

The temperature in the mine remains uniformly between 55 deg. and 60 deg. winter and summer. It is quite noticeable that there are rarely any explosions during the summer months when the absolute humidity is high. Whenever the dew point of the external air is above the temperature of the mine, moisture is deposited on the walls of the mine. However, when the outside dew point is below 55 deg. the air remains unsaturated and the mine becomes dusty. In extremely cold weather the moisture content of the air is very low, and the air when heated in the mine to approximately 55 deg. has an exceedingly low percent of humidity. This causes the walls to dry so rapidly that it is impossible to keep them moist by any of the usual means of spraying. By use of proper air conditioning apparatus in connection with the air supply, summer conditions may be reproduced in the mine without any appearance of fog, or other objectionable features, and the mines may thus be kept in a perfectly safe condition where it is now an impossibility.

DISCUSSION

Mr. A. R. Raymer: How is the humidity controlled during the winter months and in summer months?

The Author: The air is heated and saturated by means of a water spray of variable temperature, this temperature is automatically controlled by means of a thermostat subjected to the saturated air temperature, so that the latter is maintained constant, say at 40 deg. By controlling the temperature of saturation a fixed number of grains of moisture are held in the air. When this saturated air is raised to the room temperature, the proper relative humidity will be secured, depending upon the difference between the temperature of saturation and the room temperature. When the outside wet bulb temperature is above the saturation temperature desired, perfect control is impossible without refrigeration.

In summer time the humidity cannot be kept as low as desired without refrigeration. In the plant I spoke of where

they had a saturation temperature of 40 deg. all the year around, this was obtained by cooling the water below 40 deg. This is the only way that humidity can be reduced except by use of some moisture absorbing chemical such as calcium chloride. But the use of this in the ordinary plant is more undesirable than the refrigeration. It imparts an odor to the air which is very objectionable. In the plant mentioned about all that can be accomplished is to prevent an increase of humidity. On exceptionally humid days this is accomplished by cutting off the sprays and using cold water through the flooding sprays on the baffle plates; the water being below the dew point of the air, will precipitate moisture from the air rather than cause it to take up more. Now I will not say that the relative humidity of the air will not be greater after it leaves the washer than before, but it will have fewer grains of moisture in it per cubic foot, and by bringing it back to its original temperature there will be a slightly lower relative humidity. A distinction must be made between relative humidity, which depends both on temperature and on moisture content, and absolute humidity, which depends on moisture content alone.

Mr. A. B. Ludgate: I would like to ask if the quality of the air, in passing through these washers, is in any way changed, and to what extent, especially as regards the chemical composition of the air proper and the contained gases, and particularly as to the amount of free oxygen in the air.

The Author: There are a large number of installations in the schools at Cincinnati where they have about every washer on the market, at least every one mentioned tonight. There they have made a bacteria test which is very interesting. By obtaining cultures of air samples they have found that the colonies of bacteria after the air has been washed have been reduced to about one-third what they were originally.

Mr. A. R. Raymer:* A plant much like Mr. Carrier has described was installed in the Pittsburgh & Lake Erie Terminal Station, about ten years ago. When it was decided to build an

*Assistant Chief Engineer, Pittsburgh and Lake Erie Railroad, Pittsburgh.

office building on the South Side, the Clinton mills, the Sligo mills and many others in that vicinity were working at full capacity and the atmosphere was extremely dirty. It was decided in the plans of that building to have the heating and ventilating system a closed system, that is, it would be complete without the use of the windows for ventilation. The plan finally decided on was the one in use in the Chicago Public Library. That consisted in general of a washing, a heating and a fan system to carry the air through the building.

In the Terminal Station the air is taken from the roof of the building down through a shaft to the basement below the waiting room floor. It is then drawn through a washer and dryer, which consists of the baffle plates you have heard described, after which the air is warmed. Then by a system of fans it is forced up to the rooms, and by another system of fans the foul air is drawn out and discharged again at the roof.

In order to understand the working of this system it will be necessary to describe in a few words the heating system that is used. It is comparable to the circulation of the blood in the human body. It is a closed system with a pump, comparable to the heart, causing the circulation. The water is forced through a heater in the power house, then through pipes to, and throughout the building. The temperature of the water in the circulating system is regulated in the power house hourly by the engineer in charge. The temperature is kept to a determined schedule which is inverse to the outside temperature. The amount of radiation for each room is computed to provide for the losses through the outside wall exposure, the window exposure and the inside wall exposure, and the whole system is arranged so that at a given temperature of water the temperature in one room will be the same as in any other. When the outside temperature changes, a corresponding change is made in the water temperature. With the adjustment of the temperature in the power house no adjustment is needed in the rooms. In fact there is no chance for it except by opening the windows or shutting the water off. While the outside temperature may vary from 20 deg. below zero up, the heat of the water is varied

to produce a constant result of about 60 deg. when the air leaves the washing plant.

The fans draw the air down the shaft from the roof at a velocity of about 400 to 500 ft. per min. It passes through a washing chamber, which is simply a chamber filled with sprays making practically walls of spray through which the air has to pass, particles of dust and dirt becoming attached to the particles of water, after which it is necessary to separate the water from the air and the dirt goes with the water. This separation is accomplished by passing the air through baffles in which the air changes direction rapidly. On account of its velocity the globules of water are thrown off by the centrifugal motion tangentially as they come in contact with the baffles and there drop to the tank and are re-circulated in the winter time and in the summer time allowed to waste. In this way the air is perfectly dry after it passes the washing chamber, as far as globules are concerned, not referring to the humidity.

In the winter time the air is heated after it is washed and dried, to about 66 deg. The radiators in the rooms raise the temperature to about 70 deg., making the maintained temperature about 70 deg. constantly through all kinds of outside weather.

In regard to humidity, Mr. Carrier has spoken very fully and I do not know that I can add much, except to give you some examples of what we have accomplished. During 1902, which was the first year after the plant was in service, we took humidity tests three times daily throughout the entire year. During the month of December the average absolute amount of moisture in each cubic foot of air was 1.4 grains. The average humidity outside, from the government reports, was 76. Mr. Carrier spoke of the absolute amount and the relative amount of humidity. That means simply this: The absolute amount is the number of grains of moisture in each cubic foot of air; the relative amount is the proportion of the total amount of saturation to the existing amount of water in a cubic foot. When the relative humidity is 75, the air is three-fourths saturated. During the same month the humidity was only 39 in the office building while the outside humidity was 76. In other words the air was much drier after it

had been washed and tempered, relatively, than it was before it was conditioned.

During the month of August the amount of moisture in each cubic foot of air was 6.3 grains, with a relative humidity of 64, and in the office building we maintained a relative humidity of 70.

About 60 000 cu. ft. of air are handled each minute by this plant. To wash this air requires about 250 gal. of water per min. at the sprays. To force this air into the rooms, three motors, two 10 h. p. each and one 7½ h. p. are used. With that amount of power handling the air into the rooms, only 10 h. p. is used in removing it. In other words the air in the rooms is under a slight pressure, the object being to have all air leaks from the inside out, rather than from the outside in, so as not to allow dust and dirt to be drawn into the room.

We made some tests to determine the amount of dust removed from the air. The quality of the dust consisted of powdered coke, ordinary soil or dirt, pulverized horse manure, and such materials. About 90 percent of that is removed by the washing plant we have, 10 percent apparently leaks through. We have the greatest trouble in removing dirt when the weather conditions are foggy combined with smoke. For some reasons which we have not been able to determine, that kind of material apparently goes through the washer. It may be on account of the smoke being more or less oily.

During the summer months the water is used once and wasted; in the winter it is recirculated and when it becomes dirty is replaced. From the amount of mud removed from the tanks we have made an attempt to determine the quantity of dirt taken out of the air. The results show something like 3500 lb. removed from the air for the whole building per year. During the summer months instead of using river water, well water which has a temperature of between 50 and 55 degs. is used. This water is used in the sprays and has a decided cooling effect on the air, the result being that we have been able to keep the temperature in the office building at a maximum of about 12 degs. cooler than the outside temperature, or an average of about five or six degs. Twelve degs. is too much difference, as

it causes chills, particularly after one has become heated; a difference of ten degrees is about the limit for comfort. The system has been generally conceded to be successful. It makes conditions in the offices much more pleasant than they could be by ventilating through the windows on account of the dust that is in that neighborhood.

A MEMBER: I would like to ask Mr. Raymer regarding the proportion of foul gases removed from the air by washing.

MR. A. R. RAYMER: We do not know what proportion of the bad gases, or good ones for that matter, are removed from the air by washing. We believe that the benefits are good but I cannot give you figures for it.

MR. E. K. HILES: My understanding of the matter is that foul gases are very largely removed by air washing apparatus which employ a fine spray. I believe Mr. Carrier touched on that in his paper when he spoke of some apparatus that has been installed in buildings in the neighborhood of rendering plants where the outside air was very offensive and the air inside the building showed a remarkable relief from the odor.

I would like to ask Mr. Raymer as to what type of spray nozzle they use and also whether they have had much trouble with clogging. I understand there are some spray nozzles, probably most of them, which employ hardened steel discs to take care of the wear due to the admission of water under considerable pressure.

MR. A. R. RAYMER: We have renewed the nozzles once I think in ten years, new nozzles being put in two or three years ago. The kind used is that you refer to, a flat disc in front of a small discharge orifice that spreads the water into a flat sheet. These nozzles are placed close enough together to make a continuous sheet of water through which the air passes, making it necessary for the air to pass through several sheets of water before it reaches the baffles.

MR. E. K. HILES: You do not experience much trouble from wear in the nozzles?

MR. A. R. RAYMER: No, not much trouble from that point. The water is reasonably free from grit and clogging matters and

there is not much trouble in the nozzles due to choking or in wearing larger.

MR. V. R. COVELL*: When the Allegheny County Court House was erected 25 years ago it was ventilated by means of fans in the basement. The basement was used as a plenum chamber from which ducts led to the various rooms. A washing device consisting of perforated pipes was also installed but as there were no eliminators the entrained water was carried through the building and the washing was soon discontinued. The air, which was drawn from the top of the tower, was heavily laden with dirt and in a number of offices the fresh air registers were always kept closed to avoid the dirt nuisance.

During the year 1907 a new ventilating and air washing system was installed under the supervision of Prof. S. H. Woodbridge. The air supply is tempered and washed by the Acme system and is then carried to the various rooms through ducts so that it is not again contaminated by the machinery and by the various kinds of work performed in the basement. The electrically driven centrifugal pumps, originally part of the air washer system, have been replaced by duplex, steam, tank pumps. These air washers are of the type shown in Fig. 1 and are giving very satisfactory results at the present time.

The new County Morgue erected about 5 years ago was also provided with an air washer of the same type. The sheet metal work was of copper held in place by galvanized iron angles and after a comparatively short service these angles were found almost rusted away. This was explained as the result of electrolysis and when the repairs were made galvanized iron was used throughout. Sufficient time has not elapsed to compare the durability.

MR. F. C. SCHATZ:† I had expected that the ventilating conditions, with which I am familiar, would be touched on by others this evening. Having failed to hear the first part of the paper, I do not know what has been said with reference to department store work.

The Company with which I am connected, have just com-

*Deputy County Engineer, Allegheny County Court House, Pittsburgh.
†Chief Engineer, Joseph Horne Company Pittsburgh.

pleted two ventilating installations of the extraction system type, one in connection with the merchandising end of our business, and the other with the toilet section. We have had in use for a number of years in our old building, an extraction system, which has always given fairly satisfactory results. The old system, which we still have in use, together with two new installations, cover the removal of foul or vitiated air in the basement, small rooms on the first floor, and all toilet rooms throughout the building. We have found that there are certain kinds of merchandise which when placed in basements, give off obnoxious odors. This we have found more especially in connection with our blanket section; in fact the location of merchandise that may have any odor connected with them has always been considered from the standpoint of placing them in the building where they would be most tolerated. In past years the toilet rooms were scattered in different parts of the building, which was due largely to the growth of the business and the expansion of the buildings. Recently all toilet rooms were placed in a separate section apart from the main building, where they have been arranged in stacks affording the maximum of natural light and ventilation, and also affording a ready means for installing a system of mechanical ventilation. The toilet rooms we were able to confine in an area 20 ft. wide by 120 ft. deep, and six stories high. This has made it possible for us to completely isolate them from our merchandising section. The system which we adopted is comparatively simple and no doubt has been used in part by others in past years. We have simply used old principles and applied them to the best possible advantage. General room ventilation has been accomplished by top and bottom registers, while all plumbing fixtures have been provided with back vents, excepting wash basins, and each fixture provided with an adjustable damper. By this arrangement the extraction of foul air becomes as near correct as is possible. Fresh air is supplied to the room by two means, either by windows which admit air from the outside, or through the doors communicating with the store, by means of ventilated panels placed in the lower sections.

The number of changes of air is about twelve per hour. The

exhaust fans are centrifugal, Sirrocco type, located on the roof and discharge the air as far above the roof as is possible.

For the basement merchandising sevtions, we concluded that it would not be very practical to install a system of fresh air ducts together with extraction ducts, owing to room conditions, as well as flood conditions which surround our premises, and therefore adopted the extraction system only, with the fan on the roof and a system of ducts throughout the basement. After considerable investigation in other establishments, we decided that it would be very essential to have the ducts and registers so arranged as to set up a circulation of air to them in all parts of the premises to be ventilated and keep every part of the air in motion, and we find after having given careful study to this feature, that we have been able to create unusually favorable conditions.

It was as late as last evening that I overheard a remark about a certain store in our city, in which a woman stated that when shopping in this particular store, she could stay but so long and then had to get out for fresh air and return again to complete her shopping. Such a condition cannot be tolerated very long by wide awake merchants and the least offensiveness in the quality of the air or temperature, must be met by them. In no case do we figure on less than ten changes an hour, and velocities at registers not less than 400 ft. a minute. Our toilet section is handled by a fan having a capacity of 36 000 cu. ft. of air per minute, and the new, east basement, section with a capacity of 45 000 cu. ft. of air per minute.

We have under way additional installations such as the two new ones above referred to, and this after having had demonstrations of the efficiency of our two latest systems.

In order to accommodate the ventilating system to the heating conditions, we have arranged for a change of pulleys on the motors for winter use, which permit of reduction of speed of fan to predetermined limits; and where further regulation is desired, this is done by means of multiple speed controllers for armature control. No doubt some ventilating experts would advocate the supplying of fresh air into the building. With us it is a question of having lots of openings on the upper floors for the

free circulation of air from without, and the expelling of fog, which in our city is a factor which must be considered. While we have to bend our energies at times to regulate the fog, yet our greatest effort is to reach into what might be called stagnant air pockets in different parts of the house and keep the air moving as best we can, and in this are fairly successful, considering the large areas with which we are obliged to deal.

There is another installation in a church in our city which may be of interest to some of our members. It contains a fresh air supply and extraction system, together with a means of cooling the fresh air entering the building. The circumstances leading up to the installation are briefly as follows: The minister at the time was anxious to be able to attract an audience in hot weather and have them feel comfortable while in the building, and the question at once arose as to whether the cooling should be done by a refrigeration plant or by means of ice supplied in cakes from the outside. The latter method was adopted. Fresh air is taken in at the roof by means of a fan placed in the basement, and the air carried up under the pews and in the aisles. The air was first washed and cooled. The foul air was taken out at the ceiling by means of a duct system which maintained a circulation of air practically throughout the entire church. Some trouble was encountered in regulating the quantity of air taken in and discharged, but this worked itself out in time. This system was followed up for perhaps two summers, when the cooling feature was abandoned. It was found that ice bills were enormous, although not as expensive as to have installed a refrigeration plant. However, both systems operating at once, that is, fresh air and exhaust, were finally accepted as being satisfactory and the use of ice discontinued. Furthermore, the system after having been in use for this length of time, showed signs of corrosion, which would have meant considerable expense to overhaul.

Mr. John Allison: I would like to ask if in the P. & L. E. Terminal Building the same system is used in the waiting room that is used in the offices? I have noticed a different odor frequently in the waiting room, but that may not be due altogether to ventilation.

MR. A. R. RAYMER: As the installation that was put in there was practically the first of its kind, we found that we had some errors to correct, which I will be free to speak about for your information. Ordinarily in ventilating an office the foul air is voided from an opening near the floor. When the heating plant and the ventilating plant were installed in our building, that method was followed. We found after one or two years use that the results were not good. It became necessary to change the ordinary practice and design something to meet the requirements. In this system the ventilating air is cooler than the maintained temperature in the rooms, consequently the best air is at the floor. The air as it remains in the room becomes warmer and goes to the ceiling, consequently the foulest air is at the ceiling. So we made a very simple inference that the ceiling was the place to void the foul air. In the mornings there was an odor of staleness. The fresh air was bypassing; as it entered the room it fell to the floor and was drawn out, and from an elevation lower than a man's head, the air became more or less stagnant during the night. After we changed the location of the openings for withdrawing the foul air, this was entirely overcome.

CONTRACTORS' PLANTS

TYPES, LAYOUT AND METHODS OF OPERATION

By Frederick E. Field*

Introduction. The subject of this paper affords so many opportunities for consideration along different lines, which are of more than ordinary interest and importance to engineers and contractors, that it is worthy of a presentation followed by discussion by engineers or contractors with many years of experience on large and varied works of construction.

The writer therefore presents this paper simply as an introduction to the subject, with the hope that it will be the means of arousing the interest of, and inducing discussion by other members of this society who are so ably qualified by their own experience to present something of value.

We visit important works either during or after construction, but it is usually the design or the completed work which interests us, rather than the plant or methods by which the contractor has accomplished the work.

We are also interested in the cost of the work as represented by the Contractor's bid, or the Engineer's final estimate, and in the engineering costs as represented by a certain stated percentage of the total cost of the work. But it is infrequent that we interest ourselves sufficiently to obtain data relative to the detail costs of construction with their relation to the organization, plant and methods employed by the Contractor, or the detail costs of engineering, dependent upon the organization and methods of the engineering force, and analyze these records for our own use or publish them for the benefit of others.

Presented at the regular monthly meeting of the Society September 20th, and published in the October 1910 Proceedings.

* Formerly Principal Division Engineer, Bureau of Filtration, City of Pittsburgh.

It would seem as if more personal and detailed study along these lines would be of mutual interest and value to both engineers and contractors.

Responsibility of the Engineer. The relation between the Engineer and the Contractor is almost one of partnership, one details and specifies the design and form of the work and the other constructs the work in accordance therewith.

The Engineer in detailing the work and estimating its cost must of necessity, take into consideration the cost of the Contractor's plant and the methods by which the work will most likely be carried on and, if it is the desire of the Engineer to make the final cost of the work as low as possible, he should, as far as is consistent with the purpose of the design and the ultimate successful operation or result of the work, so detail the design as to simplify the construction work and lessen the cost to the Contractor.

Very frequently details of design, minor measurements of the various structures, or the composition of materials are made different in different parts of the work, apparently without either theoretical or practical reasons, with the result that the Contractor is put to unnecessary expense of labor or the use of special plant, thereby increasing the total cost of the work and delaying progress.

For example, several different sizes of ballast and proportions of ingredients are often specified for concrete in adjoining parts of the same work, which make it difficult for the Contractor to carry on his work in a systematic manner without complicated plant and greatly increased cost. Without detriment to the work and possibly without even minor changes in detail measurements, the Engineer, with more complete knowledge of contract work, could have reduced the number of classifications of concrete or specified an average size of ballast suitable for all classes of the work and in these particulars alone, lessened the cost of the work. In one of the Filtration contracts where 1-2-4 and 1-3-5 concrete were specified and bid for under different prices, the Contractor of his own volition, furnished 1-2-4 concrete exclusively and probably more economically, on

account of lessened expense in handling but one grade of concrete together with a simplified method of operations and more rapid progress. Again it frequently happens that for hydraulic reasons alone, concrete conduits or sewers are slightly increased or decreased in size at frequent intervals, thus requiring a large number of forms of slightly different dimensions. If the number of sizes were decreased and the larger rather than the smaller built, not only would the frictional conditions have been improved, but the cost of the work lessened on account of the Contractor bidding a less price per cubic yard for concrete in proportion to the reduction in labor and materials required for forms.

The above illustrations will indicate the close relationship between the Engineer and the Contractor and how the Engineer, without decreasing the effectiveness of the design, can frequently, by proper consideration of the Contractor's part of the work, obtain equal if not better construction results together with better progress and a lessened cost of the work as a whole.

Responsibility of the Contractor. The Contractor probably feels a greater financial responsibility than the Engineer as he is personally interested in the actual cost of the work and realizes far better than the Engineer the effect of minor, or detail, matters in the cost of the work.

The plant and methods of operation should be fully determined before completing the bid and these matters should receive most careful and serious consideration.

The plant for each of the several divisions of the work must not only be adequate for the particular work in question but must also form an efficient unit in the plant as a whole, and should neither interfere with or delay the general progress of the work.

Changes in plant or methods after work has begun are usually very costly. Plant and methods once determined, should not be changed at the whim of some sub-foreman or assistant superintendent, who has naturally a greater interest in matters which affect that portion of the work for which he is personally

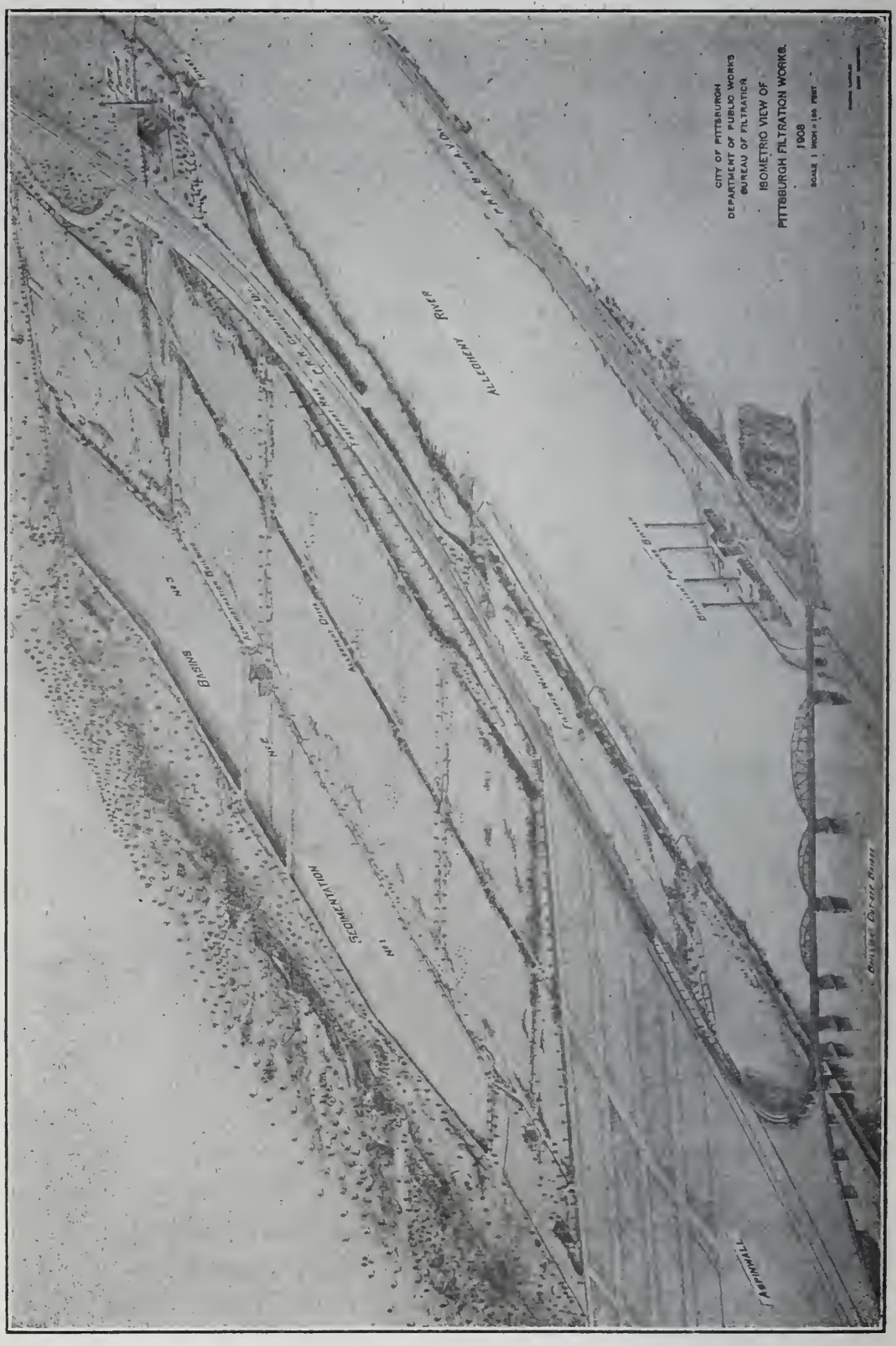

Fig. 1. Isometric View. Pittsburgh Filtration Works

responsible than in the general progress and successful completion of the entire work.

Unforseen difficulties or conditions will undoubtedly arise on all works of magnitude, covering long periods of time, which make changes in plants and methods necessary. These should be made only after most careful consideration as to their effect on the work as a whole, and after the best course of precedure is determined, the general order of work should be re-adjusted to meet the new conditions.

It is impossible to consider the Contractor's plant and methods of operations without mention of the Contractor's organization. No matter how carefully and wisely the determination and layout of the plant and how systematically the work has been started, without an experienced, well balanced, loyal, harmonious organization under efficient leadership, the Contractor has very little chance of having a balance on the right side of the ledger at the completion of the work.

With these introductory remarks, let us consider the layout of plant and the methods of operations of Contractors on several parts of the work in connection with the construction of the Filtration Works of the City of Pittsburgh.

Some features of this work are particularly interesting as similar work on several contracts was done by different contractors and the methods employed offer excellent opportunities for comparison.

PITTSBURGH'S FILTRATION WORKS

Location. The Filtration Works, shown in Fig. 1, are located just above the Borough of Aspinwall on the north bank of the Allegheny River, about seven miles above its junction with the Monongahela River to form the Ohio River. It occupies a tract of approximately 200 acres, with a river frontage of 3 700 feet. The Ross Pumping Station and the filtered water reservoir are on the low ground between the railroad and the river, and the sedimentation basins and filters are on higher ground north of the railroad.

Contracts. The majority of the work was awarded in the spring of 1905 under contracts as follows:

Contract No.	Work	Final Estimate
1, 1-A, 1-B, 1-C	Sedimentation basins and 46 one acre filters	$3,359,971.49
2	Filtered water reservoir	415,245.28
3	River crossing	266,474.36
4, 5, 6, 7, 8.	Ross Pumping Station and equipment	848,827.65
9	New engines and boilers, Brilliant Pumping Station	218,028.37
10	Pipe line, Highland Reservoirs to South Side	555,250.76
	Total	$5,663,797.91

Late in Fall of 1908, contracts for extensions were awarded as follows:

Contract No.	Work	
11 and allied Contracts	Ten additional one acre filters and appurtenances	*$745,661.49
	Grand Total	$6,409,459.40

*Partly estimated as work on some contracts is not completed at time of writing.

As the work under contracts Nos. 1, 2 and 11 is similar in many respects, these contracts, alone, will be referred to and only the main items of work will be considered, namely:

a Earthwork.

b Concrete Work.

c Filter Material.

Mr. J. D. Stevenson, in a companion paper, has taken up the subject of "Forms for Concrete" and it will therefore be necessary under this item to consider only the plant and methods of work.

The large quantities of materials handled under these contracts and the value of the main items of work, is shown in Table No. 1.

Contract No. 1 is divided into two parts, i. e. basins and filters, as the work under each is more or less distinct and was in fact practically carried on as separate contracts.

Important Sub-Divisions of Work	Contract No. 1				Contract No. 2		Contract No. 11	
	Basins		Filters		Filter	Water Res.	Filters	
	cu. yd.	Value	cu. yd.	Value	cu. yd.	Value	cu. yd.	Value
Excavation	258 790	$ 76 708.36	391 560	$ 122 009.14	120 625	$ 37 277.50	183 470	$ 62 228.40
Embankment and Filling	172 621	27 915.58	419 932	49 194.52	212 365	61 272.05	186 346	66 228.90
Concrete	40 428	247 592.64	174 007	962 272.50	38 347	217 264.80	31 582	237 391.20
Filter Gravel	.....	.....	52 300	52 300.00	.....	.....	16 000	27 840.00
Filter Sand	.....	.....	215 900	183 515.00	.....	.....	30 000	44 700.00
Totals	471 839	$352 216.54	1 253 699	$1 369 291.16	371 337	$315 814.35	447 398	$439 105.50

Table No. 1

GENERAL LAYOUT OF CONTRACTORS' PLANTS

CONTRACTS NO. 1, 2 AND 11

The general arrangement and layout of the contractors' fixed plants for the greater part of the filtration work is well shown in Fig. 2, which has been made up from data obtained from time to time as the work progressed.

CONTRACT NO. 1

Camps, Stables, Shops and Dock. The main camp for laborers, upon all contracts awarded in 1905, was located at the east end of the City's property, upon the site of the ten additional filters later built under Contract No. 11. At the west end of the property and along the County Road were located the Contractor's stables. Nearly all of the available land south of the filters and north of the Freeport Road was occupied by the Engineers and Contractors offices, carpenter shop, machine shop, and cement sheds. The land south of Freeport Road and between the railroad and the river was largely low land frequently flooded at times of high water and therefore unsuitable for camps, shops or storage of material.

On the river bank directly opposite the center of the plant was erected the Main Dock, shown in Fig. 3, equipped with boilers, derricks, hoisting engines and other machinery for unloading and distributing sand and gravel dredged from the river bed.

Tramway System. Early in 1905, the Contractor erected the "Tramway" or "Trenton System" for the handling of concrete materials. This consisted of an over head rail supported by wooden trestles, extending from the dock and surrounding the first 24 filters, and carrying an endless cable, kept in motion by machinery at the dock. By this means, steel buckets, of about one cubic yard capacity filled with sand, gravel or cement were drawn along the line of the tramway and emptied at the several concrete mixers placed beneath the cable where work was in progress.

The tramway system for local distribution about the work, proved to be a failure and after a few month's trial was torn

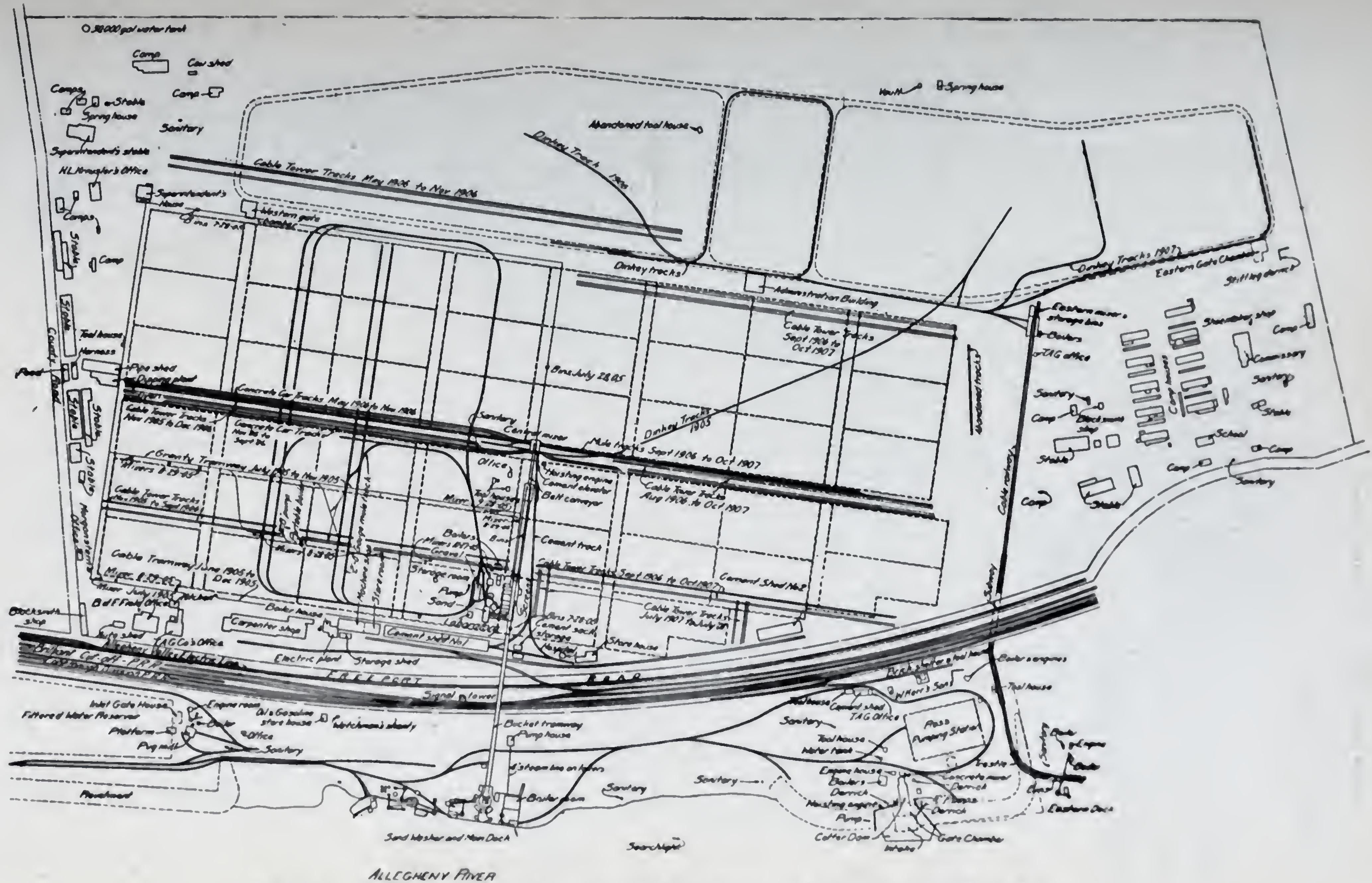

Fig. 2. Contract No. 1. General Layout of Contractor's Plant

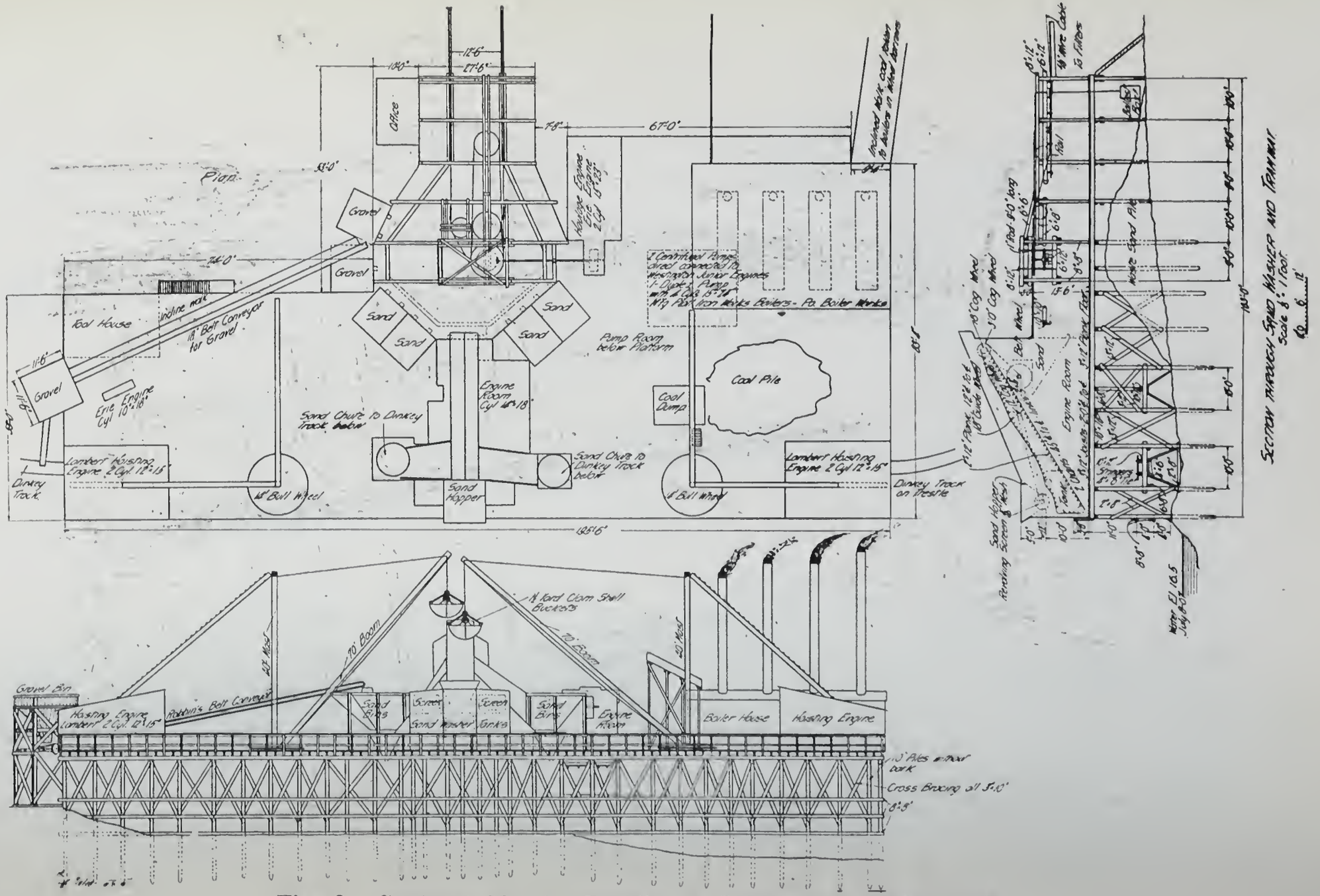

Fig. 3. Contract No. 1. Details of Contractor's Main Dock

down and replaced by a central mixer and cableway system which was first operated in November 1905.

Cableway System. The central mixer, shown in Fig. 4, consisting of two Haines mixers, was located at the intersection of the main line of the tramway from the dock and the drive separating the north and south batteries of filters. Between this point and the dock the old tramway system was reconstructed so as to deliver sand and gravel to storage bins located south of the mixer. Beneath these bins was a tunnel in which was installed two endless belts for conveying the sand and gravel to small storage bins above the concrete mixers. See Fig. 5.

Three cableways were erected, two spanning those filters north of the central mixer and the third spanning a portion of those filters south of the mixer. The location of the tracks upon which the cable towers operated are clearly indicated in Fig. 2, and the design of the towers in Fig. 6.

Eastern Mixer. For the concrete ork in the sedimentation basins, the Contractor built an entirely separate plant which was not ready for operation until April 1906.

A small dock, equipped with derrick, hoisting engine and receiving bins, was built on the river bank just east of Ross Pumping Station. From this point a surface cable for conveying sand and gravel led up through the subway to the eastern mixer, shown in Fig. 7, which was located south of the center line of Basin No. 3. Here two Foote concrete mixers, received the sand, gravel and cement from overhead bins and discharged the mixed concrete into wooden side dump cars which were hauled by dinky locomotives to the work.

Filter Material. The gravel plant for sizing and washing the filter gravel dredged from the river and unloaded at the dock, was located under the line of the tramway and east of Filter No. 24. See Fig. 8. The gravel screens were cylindrical, about $3\frac{1}{2}$ feet in diameter, with alternate sections of screens and plate. This was revolved about a horizontal axis and the screened material collected into bins below, from which it was raised by a clam shell bucket and deposited in distributing bins, elevated above the roof of Filter No. 24. The gravel was transported from these bins to the filters by means of special steel

hopper cars drawn by mules along a system of narrow gauge tracks laid upon the completed filter roofs.

The plant for the preparation of the filter sand was located on the main dock where the raw material was unloaded, see Fig. 3, and consisted of a large tank in which the sizing and washing was accomplished by an upward flow of water. The prepared sand was then carried by the tramway to a bin near the gravel screens from which it was removed by belt conveyors and placed in elevated distributing bins, erected on the roof of Filter No. 24, and was later transported to the filters by the same system of cars and tracks used for the filter gravel.

CONTRACT NO. 2

Concrete Plant. At the beginning of the work the concrete materials were mixed in a cubical mixer on the main dock and conveyed in steel, side dumping cars, hauled by dinkey locomotives along tracks just outside the south line of the filtered water reservoir. These cars were emptied by means of chutes into smaller cars which were pushed by hand along temporary narrow gauge tracks to where work was in progress.

After the first season, 1905, this method was abandoned. A Haines mixer was erected just west of the main dock from which the mixed concrete was conveyed in buckets on flat cars to within reach of a cableway system spanning a portion of the reservior.

The concrete in the river revetment was transported along tracks laid parallel and close to the line of the work, in wooden side dumping contractor's cars and delivered by means of chutes where desired.

CONTRACT NO. 11 AND ALLIED CONTRACTS

Concrete Work. A Haines mixer, similar in arrangement to those used on Contracts No. 1 and 2, was erected on the river bank near Ross Pumping Station. Cement was unloaded from cars on a railroad siding near by, conveyed by means of flat cars to the mixer and raised by an elevator to the mixing platform. Sand and gravel were unloaded from barges and placed in small storage bins above the mixer by a derrick and clam shell bucket. The mixed concrete was conveyed in 3½

cubic yard special steel buckets, upon flat cars hauled by dinky locomotives on a track laid through the subway to within reach of a cableway system spanning the filters from north to south.

For certain portions of the work which were out of reach of the cableway system, a stiff-leg derrick was employed to lift the buckets of concrete where desired.

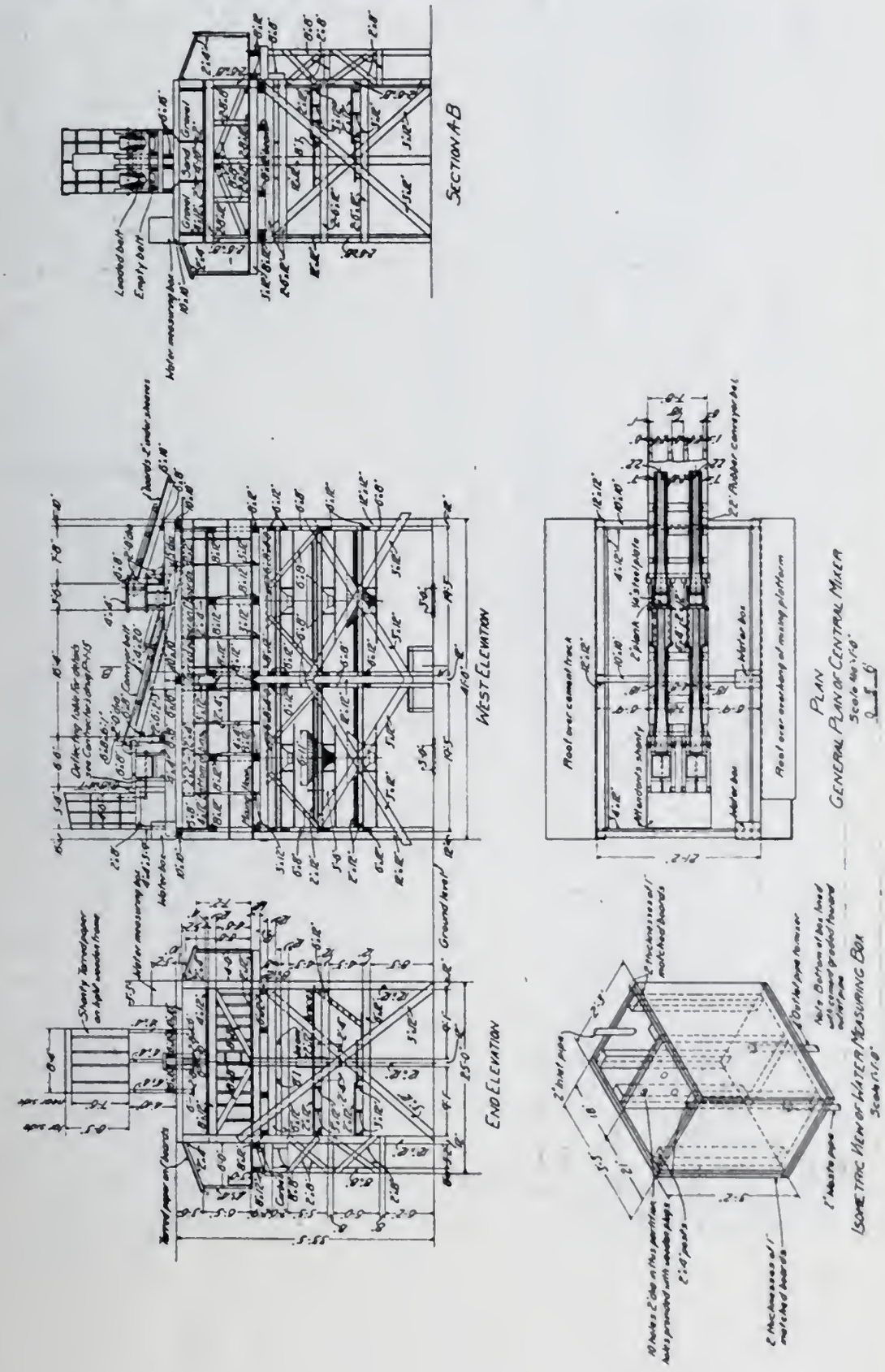

Fig. 4. Contract No. 1. Details of Central Concrete Mixer

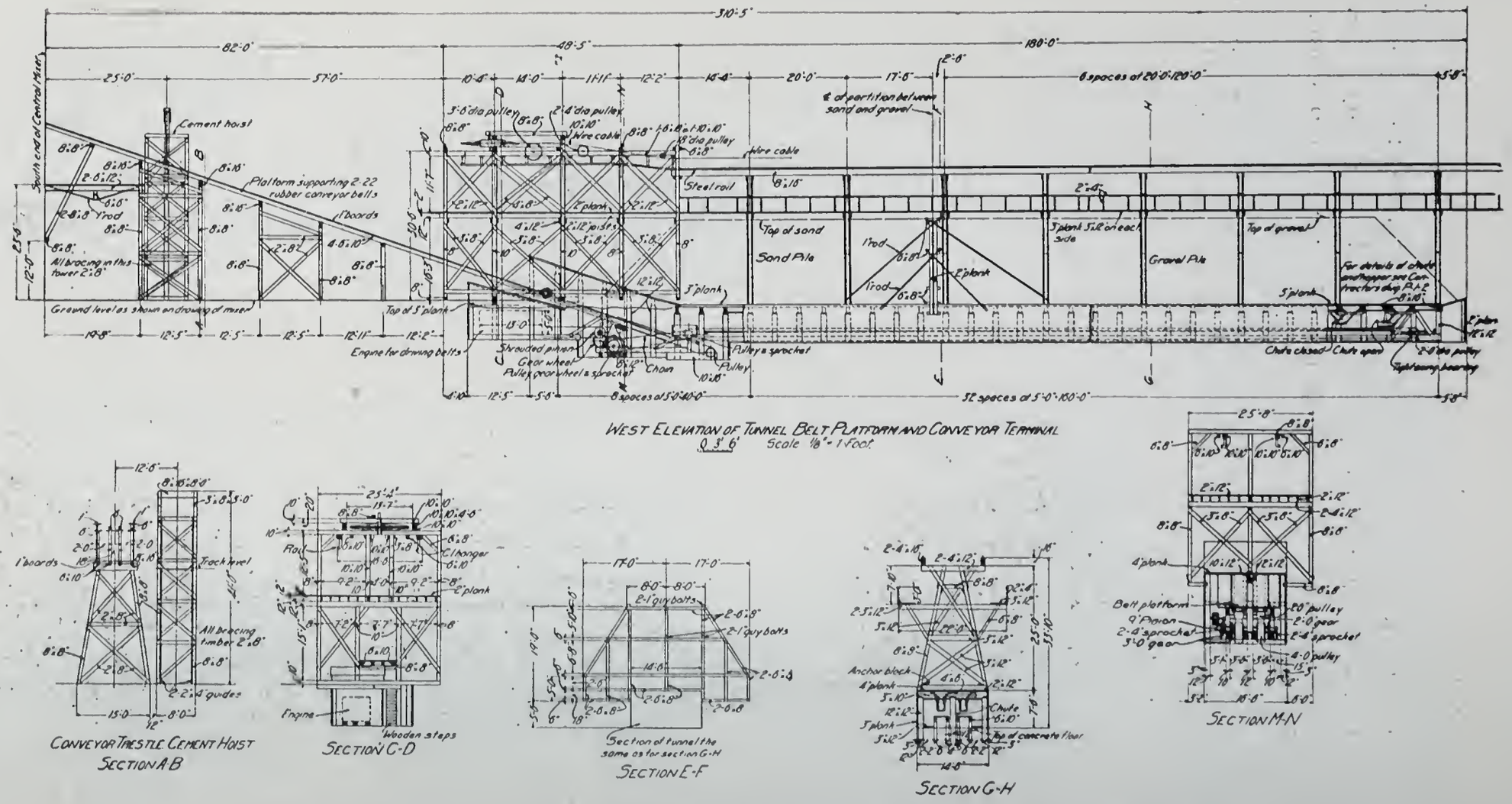

Fig. 5. Contract No. 1. Details of Tramway at Central Concrete Mixer

Filter Material. A sand digger, equipped with both a gravel and a sand washing plant, was able to prepare the filter sand and two sizes of the filter gravel directly on the boat. The other two sizes of filter gravel were sized and washed but not separated until brought to the receiving bins which were a part of the remodeled concrete mixer for this contract. Here the two mixed sizes were separated by passage through a revolving screen and dropped into distributing bins below. From these latter bins the several classes of filter material were hauled in trains of two cars, each of 2 cubic yard capacity, by means of an electric locomotive on a double trolley system, up through the subway and over the tops of the filters and dropped through openings in the filter roofs into cars running upon the permanent filter track system and thus distributed within the filters.

METHODS AND OPERATION OF WORK

EARTHWORK

Contract No. 1. The excavation for the sedimentation basins varied from one to fifteen feet in depth, the material being either sandy clay or sandy gravel. The top soil was first removed by plow and scoop teams, or by a grader hauled either by horses or a traction engine, and placed in storage piles for subsequent use. The greater part of the subsoil was too heavy for this method of handling and was therefore excavated by steam shovel and hauled either to the embankment in bottom dump wagons or to a pile of surplus material in wagons, or in cars drawn by dinkey locomotives.

The drainage of the excavations was inadequate and this, together with a somewhat rainy season, resulted frequently in the entire cessation of operations or the carrying on of work at great disadvantage. Often the material excavated and placed in embankment was too wet to be satisfactorally compacted without being allowed to dry out for a considerable time before rolling which made progress slow and the work expensive.

During the first season, 1905, the excavation and trimming was not pushed so that the concrete lining could not have

been placed even if the concrete plant had been installed and even during the second and third seasons delay and lack of system in excavation and embankment work often hampered progress in other operations.

The basin excavation, amounting to 260 000 cu. yd., engaged the time of the Contractor from April 1905 to October 1908. The average daily excavation during this period would therefore be less than 300 cu. yd. and as over 25 percent of the total excavation was surplus material which could readily be handled during the winter months, greater progress was to have been expected.

On the filters, the excavation was uniformly about four feet in depth, the material being river silt with little gravel. The top soil was first removed either by plow and scoop teams or by grader and wagons and placed in storage piles for subsequent use. Much of the subsoil was handled in like manner although after the first season considerable of the excavation was done by steam shovel. The price bid for excavation and placing excavated materials in embankment, 40 cents per cu. yd., evidently did not contemplate but one handling of the material. The work was however so conducted that much of the excavated materials were first removed to storage piles and later re-excavated and placed in embankment or over the filter roofs. This necessitated long hauls and rehandling of excavated materials and resulted in the work costing more per cubic yard than the price bid by the Contractor.

Part of this extra cost should be charged against the tramway system, as its arrangement and the work done by it, made subsequent work by the cableway system, disjointed as to continuous and systematic progress.

A different method of procedure, outlined below, might possibly have greatly reduced the cost of this work.

First. Complete the excavation for six or twelve filters, placing the excavated materials in temporary storage where it would be available for convenient rehandling and use as embankment or filling, if surplus material was required near the completion of the work.

Second. Carry on the concrete work continually from north to south or from east to west, completing all main structures as this work progressed.

Third. Carry on the rest of the excavation work parallel with the advance of the concrete work, placing the same directly

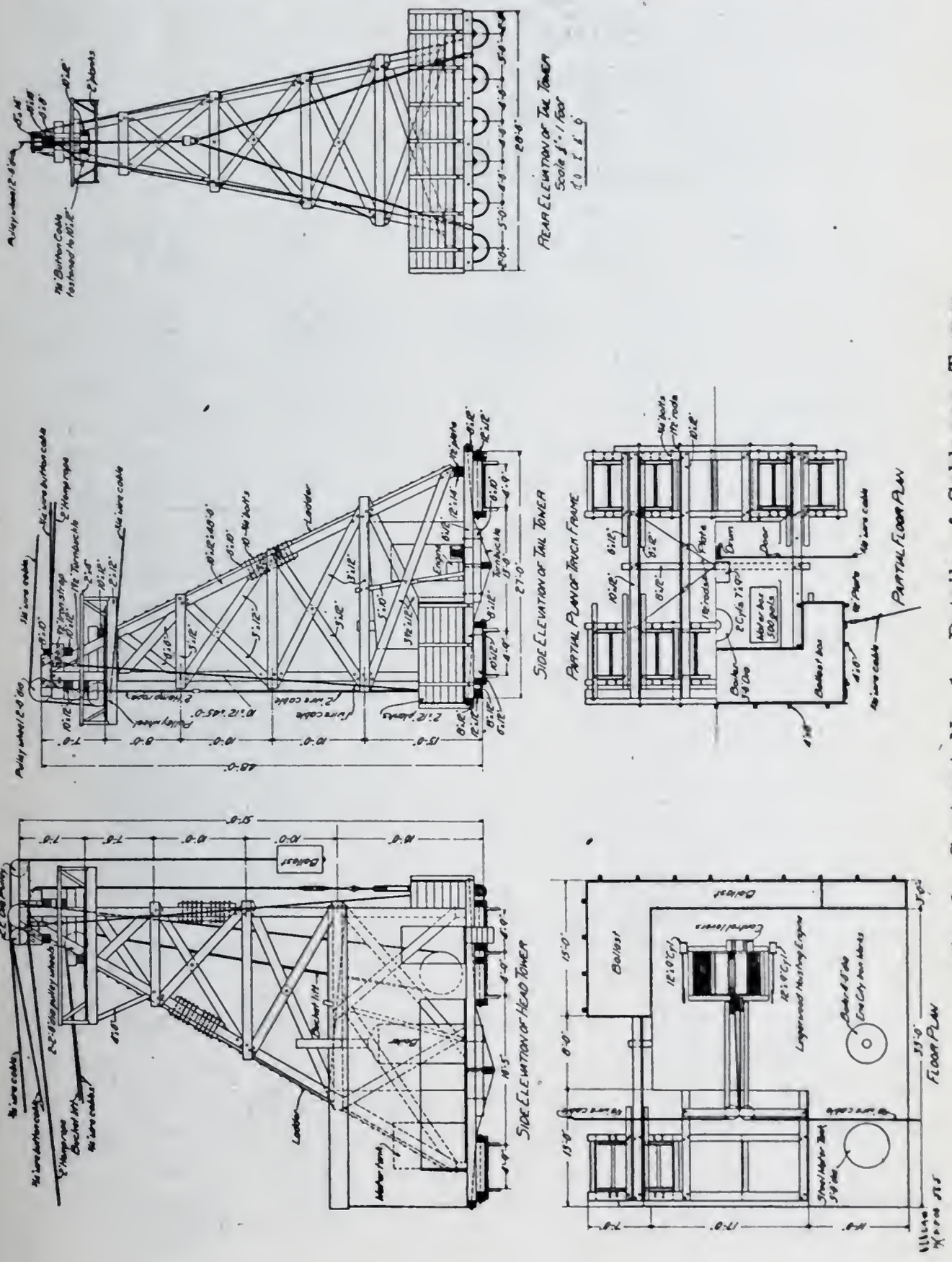
REAR ELEVATION OF TAIL TOWER
SIDE ELEVATION OF TAIL TOWER
PARTIAL PLAN OF TRUCK FRAME
PARTIAL FLOOR PLAN
SIDE ELEVATION OF HEAD TOWER
FLOOR PLAN

Fig. 6. Contract No. 1. Details of Cableway Tower

in embankment or over the filters without rehandling, as the amount of excavation per filter was practically equal to that required about the walls or for over vaulting.

Contract No. 2. The average depth of excavation on this

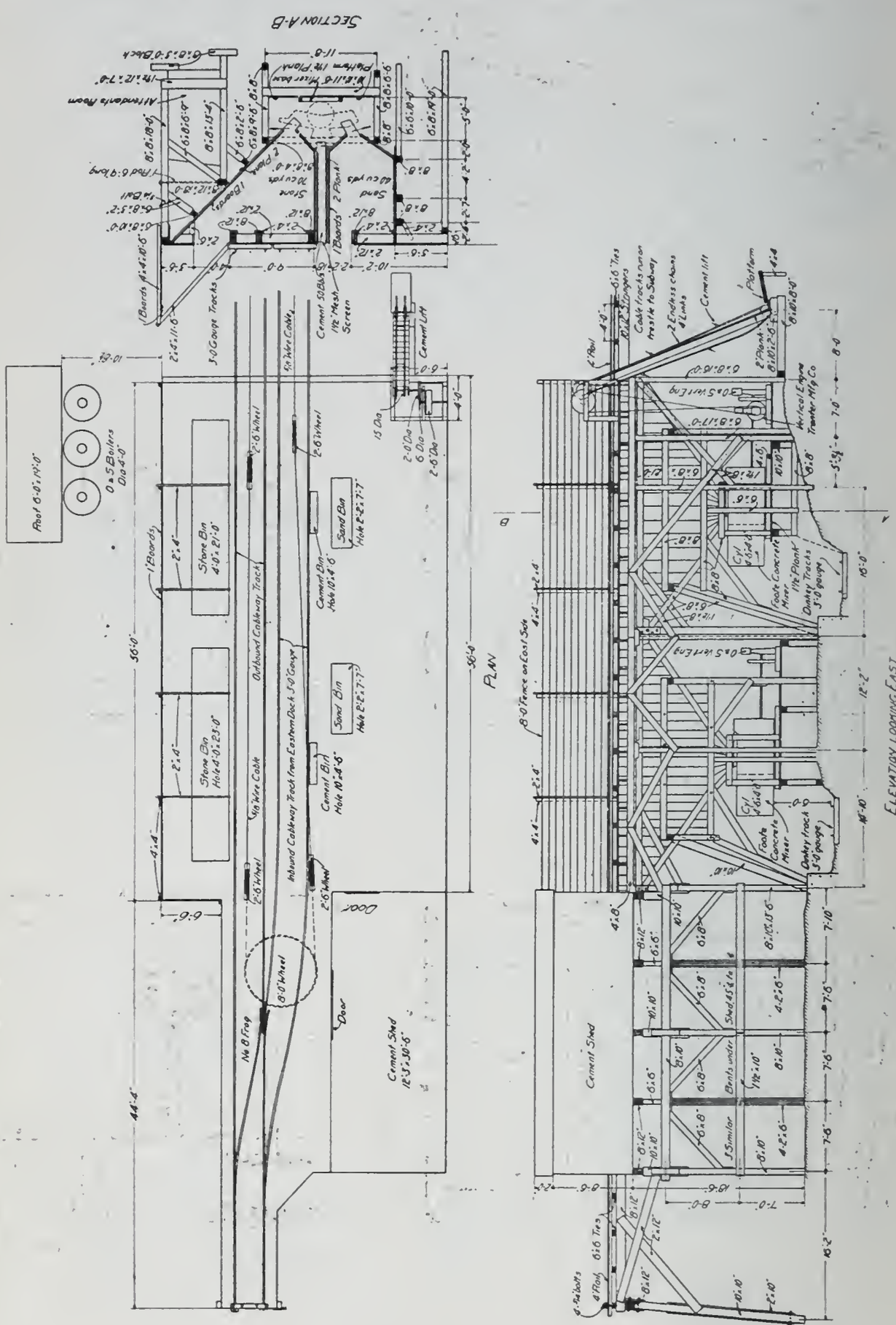

Fig. 7. Contract No. 1. Details of Eastern Concrete Mixer

contract was about 12 ft., the material being a sandy gravel. After the removal of the top soil by plows and teams, the excavation of subsoil was made by steam shovel, the materials being placed either in the river and wall embankments or in a temporary storage pile east of the reservior. The limited space between the reservior proper, and the railroad and river bank prevented economical disposal of excavated material and after the cableway tracks were laid, the available space was still further cut down so that much of the excavated material was rehandled at additional expense to the Contractor.

Contract No. 11. As previously stated, this contract was awarded late in the fall of 1908. The Contractor first removed the top soil by plow and scoop teams and stored this material beyond the north line of the filters and against the south embankment of Basin No. 3 so as to provide sufficient width for the tracks of one cable tower. This material was also conveniently placed for later removal and spreading over the completed embankments and filling.

A steam shovel was then put into operation, first making a cut entirely across the work from west to east and on the line of the gallery, the excavated materials being loaded into trains of contractors side dump cars and hauled by dinkey locomotives to land reserved for the disposal of surplus material. The material was a sandy gravel and the average depth of excavation was about 12 ft. Excavation continued in the same manner during the winter so that when work opened in the spring of 1909, over 60 percent of all the excavation work was completed, including the gallery and the five filters to the north. As this material was in excess of that required for embankment and filling for the filters it required no rehandling at a later date.

The subsequent rapid progress on the concrete work made it possible to move a large proportion of the remaining excavation directly into embankment and filling over vaulting, thus making the amount of material rehandled a minimum. As the price bid for excavation and placing the materials in embankment or filling was 75 cents compared with 40 cents per cu.

yd. on Contract No. 1 these items of work were, due to good management of the work as a whole, very profitable to the Contractor.

CONCRETE WORK

TRAMWAY SYSTEM

Contract No. 1. This system, put into operation in July 1905 about four months after the award of the contract, had, as far as the writer has knowledge never before been used on similar work and during the short time it was in operation proved to be entirely unsuited for the work for the following reasons:

First: Operations were frequently at a standstill due to cable troubles or to failure of the stringer supporting the track upon which the buckets filled with cement, sand and gravel travelled. These breakdowns usually occurred when two or more buckets were allowed to come at one time upon a single stringer, and on one occasion between 300 and 400 linear feet of the tramway fell to the ground like a pile of blocks. A break or other trouble anywhere along the 5000 foot length of the tramway entirely shut down all concrete work at a moments notice as there was no adequate storage facilities at the individual mixers. The demoralizing effect of such accidents on the Contractor's order of work and the resultant slow progress need no further mention.

Second: The output from the concrete mixers was small on account of the mixers being of $\frac{1}{2}$ cubic yard capacity and to the inconvenient arrangements for proportioning the materials by weighing.

Third: The wheel barrow method of transporting concrete 300 feet to and from the mixer was not helpful to rapid progress not only on account of the small amount carried at one time but also to the interference with the work of erecting forms and other work. See Fig. 9.

Fourth: Apparently the system to be used for placing concrete in the vaulting had not previously been carefully studied out, for when this was first attempted it was found that

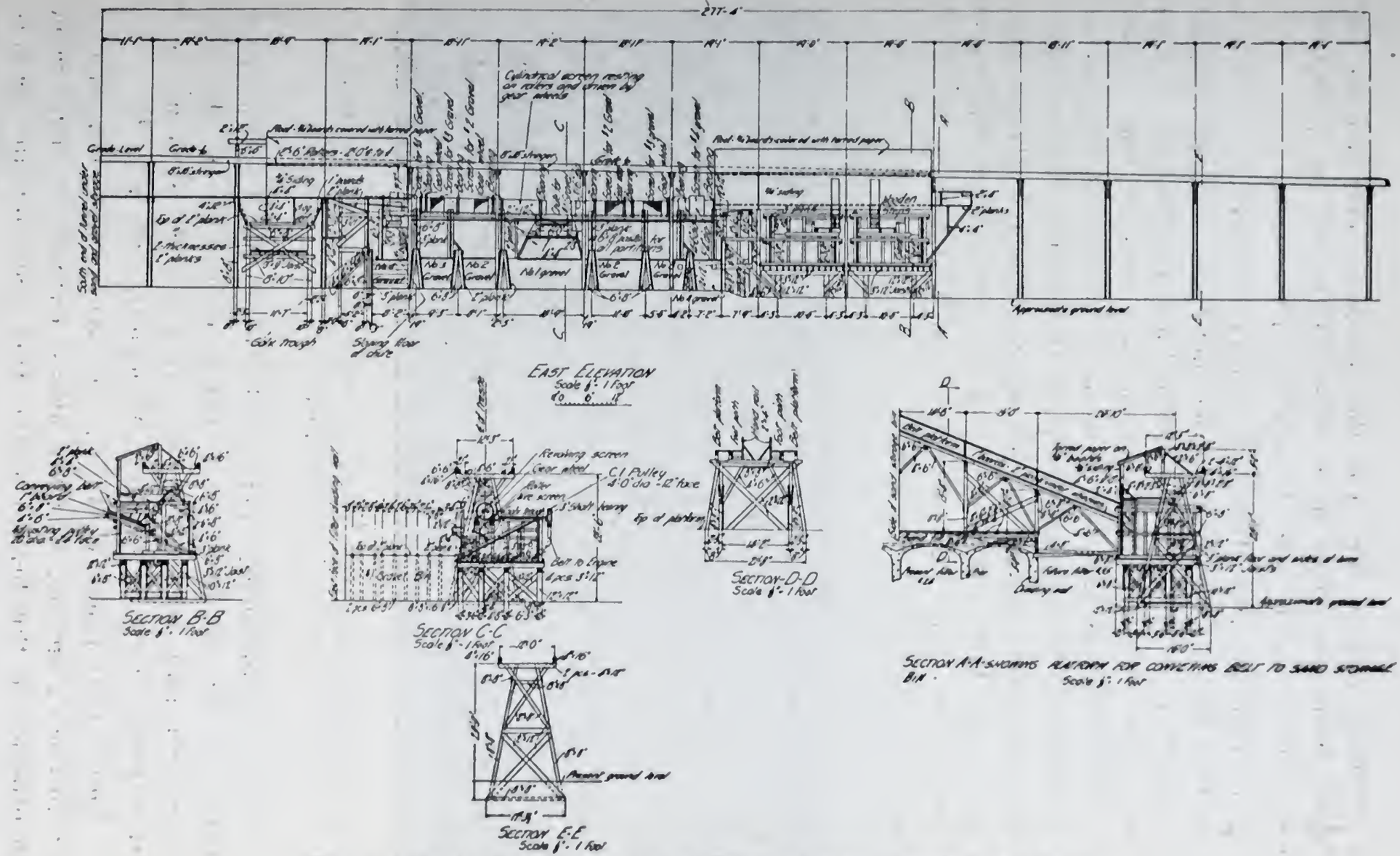

Fig. 8. Details of Tramway at Filter Gravel Screening Plant

the tramway was so low that the concrete could not be discharged from the mixer at a level convenient for its subsequent transportation over the roofs of the filters.

To overcome this difficulty, various methods were tried. An endless belt supported on an inclined frame was installed for the conveyance of the mixed concrete from the discharge hopper of the mixer near the ground level to a point at such height above the filter roof as would allow it to be dropped into cars or wheel barrows for transportation to the work. This arrangement was entirely unsatisfactory as the mixed materials were separated in their passage up the belt, much of the liquid cement was lost and the concrete required remixing by hand before being placed in the work.

Fig. 9. Contract No. 1. Tramway System. Placing Concrete in Filter Floors

Later, arrangements were made for conveying the mixed concrete in cars to an elevator which lifted them to the level of the filter roof over which they were pushed by hand on a narrow gauge track to the place of deposit. See Fig. 10.

Under the tramway system, all forms were required to be transported and set in place almost entirely by hand labor and progress in this branch of the work was slow and tedious.

The tramway system was in operation less than two months

before the Contractor decided to abandon this system and at once replace it by a central mixer and cableway system.

CABLEWAY SYSTEM.

When this system was decided upon, the concrete work was well advanced on filters No. 9, 10, 11, 12, 23 and 24 and the vaulting had been completed over the south half of filters No. 11 and 12.

The layout of the cableway system was of necessity largely controlled by the location of buildings and plant and the work completed, and therefore the effective operation of this system was seriously handicapped.

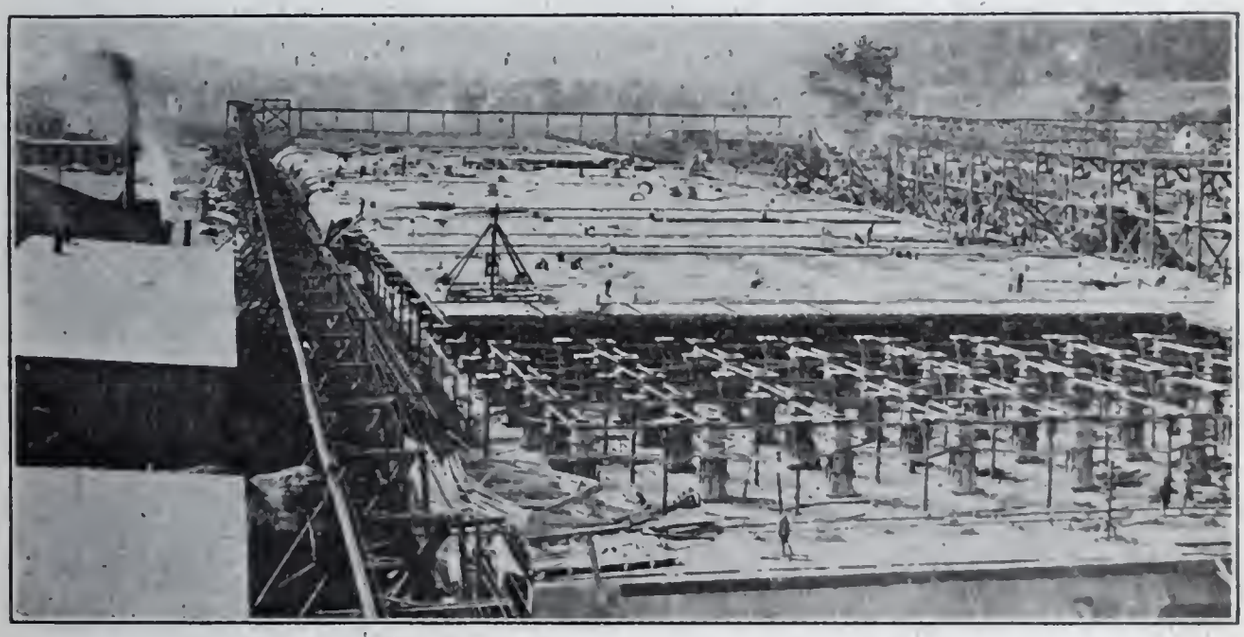

Fig. 10. Contract No. 1. Tramway System. Placing Concrete in Piers and Vaulting

The tracks for the tail tower of one cableway were laid on the completed floors of filter No. 9, 10, 21 and 22 and just north of the south row of filters and the head tower of the same cableway ran upon tracks between the north and south batteries of filters, which tracks also came within the lines and prevented work on the southern ends of the filters north of the Allegheny Drive. The other two sets of cableways had their head towers on these tracks and their tail towers upon the tracks in the bottom of basin No. 1.

It is thus seen that the location of these cable tower tracks

directly within the lines of the work could only result in splitting the work up in small units, delaying and making most inconvenient the completion of those sections of the work encroached upon by the cable tracks and thereby increasing the cost of the work to the contractor.

The mixed concrete from the central mixer was hauled in buckets upon flat cars along tracks parallel with the cable tower tracks in the Allegheny Drive to within reach of the cableway which then lifted and conveyed it where desired.

Notwithstanding all the hindrances to the effective operation of the cableway system very good progress was made although at a cost to the Contractor in excess of what would have obtained if the cableway system had been installed in the first place.

Table No. 2 gives the number of cubic yards of concrete placed by the tramway in 1905 and by the cableways during the same months in 1906.

Month	1905 Tramway cu. yds.		1906 Cableway cu. yds.	
	Total	*Daily Average	Total	*Daily Average
July	1520	60	16 541	661
August	3183	127	12 270	490
September	5192	207	12 143	485
October	4416	177	12 969	518
TOTAL	14311	....	53 923	...
DAILY AVGE		143	.....	539

*Daily Average based on 25 days per month.

Table No. 2. Tramway vs. Cableway in Concrete Work

The records show that during 1905 under the tramway system, less than 10 percent of the total amount of concrete to be placed by either system was handled, while in 1906 under the cableway system over 50 percent or 5 times as much concrete was placed and in 1907 35 percent of the concrete was placed. The slowing up of the work in 1907 was largely due to conditions brought about by the early installation of the tram-

way system and the completion of small isolated portions of the work, thus decreasing the number of places where operations could be carried on.

The sand and gravel for the concrete was brought to the work by the same method in each case, namely, by the main tramway system, which was strengthened, from the main dock, and therefore the superiority of the cableway system as compared with the tramway system may be attributed to the following reasons:

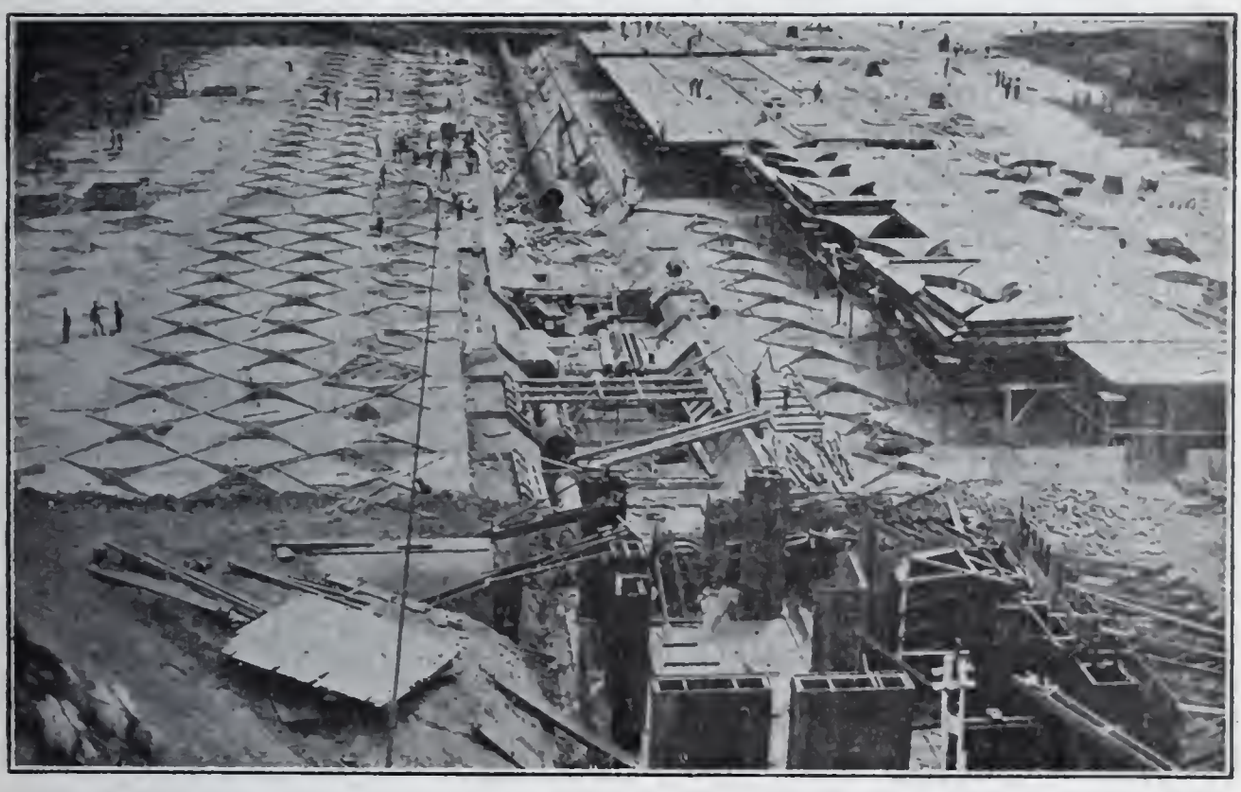

Fig. 11. Contract No. 1. Cableway System. Progress on all Main Items

First: The facilities for storing a large supply of sand and gravel near the central mixer and separate machinery for conveying the materials from these storage piles to the mixer; thus making the output of the mixer practically independent of any decrease of output of the sand and gravel from the river, or breakdowns of machinery on the dock or of the tramway and in fact allowing the dock and tramway to be used for handling filter material for a considerable portion of the time without delaying the concrete work.

Second: The central mixing plant, which was equipped with Haines mixers, had a capacity always more than adequate

to the demand of the work, and, was able to produce a better and more uniformly mixed product than had been possible under the system of individual mixers located at various points throughout the plant.

Third: The facilities for transporting the mixed concrete from the mixer to the place of deposit, sometimes a distance of 2500 feet, within a few minutes, without stratification of the mixture, or loss of liquid cement, so that a minimum amount of labor was required to properly compact it within the forms.

Fourth: The carrying of the buckets of concrete high in the air above all other work and the large area covered by one cableway, allowed all other divisions of the work to proceed without interference and in an orderly and systematic manner, one class of work being kept at a sufficient distance from another to prevent delays or damage to "green" concrete. See Fig. 11.

Fifth: The handling of forms, particularly arch centers, was done far more rapidly and at less cost by the cableway than was possible by the hand methods required under the tramway system. It was possible after all the concrete, which could be finished by quitting time, had been placed, to transport and set in place ready for final adjustment and bracing by the carpenter a sufficient number of forms for the next day's work and if the concrete work was crowding the form work as frequently occurred towards the end of the week, it was entirely possible by using the cableways on Sunday, when concrete work was shut down, to again get the form work well in advance of the concrete work.

The handling and setting of pipes and sluice gates was also frequently done economically and conveniently by use of the cableways.

EASTERN MIXER AND HAULAGE SYSTEM

The concrete work in the sedimentation basins included the placing of a six inch lining on the bottom and inside slopes, and a 12 inch layer, upon a bed of gravel, on the inside slopes between low and high water. As this work was not compli-

cated by other work and only amounted to 40 000 cu. yd., or about 25 percent of the total amount of concrete in the filters, it would seem that this work could have been more economically done by the central mixer and cableway system and thus avoided the additional expense of a separate dock, surface cable railroad and separate mixing plant. The basin work was started in April 1905 and was practically completed in April 1908.

Leaving out the four winter months there would remain about 25 months actual working time which gives an average daily output of concrete of 60 cu. yd. The concrete work was however not started until April 1906 and to have finished the

Fig. 12. Contract No. 2. Placing Concrete before installing Cableway

work at the same date, namely April 1908, would have required under the same conditions an average daily output of about 100 cu. yd. per day. The capacity of the central mixer was sufficient to handle this additional amount and it was conveniently located for the work.

Contract No. 2. The concrete progress made during the first season, 1905, was very unsatisfactory owing to the inefficient plant and the crude hand methods for carrying on the work. See Fig. 12. After the cableway system with Haines mixer was put into operation, the work proceeded rapidly and the effectiveness of a cableway system for work of this character

was evident. See Fig. 13. The handling of the roof forms which had to be supported on piers 21 feet high would have been a difficult undertaking without the use of the cableway. Also the placing of concrete in small batches either by wheel barrow method or by cars on a narrow gauge track system on work requiring thin layers in comparatively large units, is inadvisable as under these conditions the best results can be obtained by getting the concrete into the work and screeding and finishing it quickly, leaving it to set without disturbance of any kind, particularly the vibration due to wheeling or hauling loads over adjacent work.

Fig. 13. Contract No. 2. Placing Concrete by Cableway

Contract No. 11. The progress on concrete work was unhampered by excavation work, which had, as previously stated, been 60 percent completed before concrete work was started in April 1909. The Contractor was therefore able, by a well arranged and effective plant and by systematic methods, to complete over 50 percent of the concrete work by July 1st, 1909 and the entire concrete work for the ten one-acre filters and gallery by November 1st of the same year. See Fig. 14. One particular feature of this work was the handling of concrete in $3\frac{1}{2}$ cu. yd. buckets so designed as to enable the concrete to be discharged, either all at once, or as desired, by means of a small circular gate in the bottom of the bucket. This allowed a

bucket of concrete while suspended from the cableway, to be swung over and along the line of a wall thus depositing concrete in thin layers within the wall forms for a distance of 15 or 20 feet and not only producing better construction results but decreasing the labor required to work up the concrete on account of its being spread with uniform consistency throughout the entire mass. Furthermore the depositing of a batch of concrete of such large size, made ample work for the concrete gang before the arrival of the next batch and tended to better progress at a less unit cost for labor. The order with which the gallery work was carried on differed from that on Contract No. 1 and was productive of better progress.

Fig. 14. Contract No. 11. Concrete Work by Cableway

On Contract No. 11, after the concrete floor was completed, the installation of the piping systems was started and entirely completed before the filter concrete work had reached such a point as to interfere with the easy handling of the pipes. After the completion of the pipe work, the concrete gallery platform was placed and this was used as a foundation for supporting and bracing the forms for gallery walls and roof.

SUMMARY

The progress made on Contracts Nos. 1, 2 and 11 under the different systems adopted is shown in Table No. 3:

MONTH	Contract No. 1 — 1905–1906 Total cu. yds.	Contract No. 1 — 1905–1906 †Daily av. cu. yds.	Contract No. 1 — 1906–1907 Total cu. yds.	Contract No. 1 — 1906–1907 †Daily av. cu. yds.	Contract No. 1 — 1907–1908 Total cu. yds.	Contract No. 1 — 1907–1908 †Daily av. cu. yds.	Contract No. 2 — 1906–1907 Total cu. yds.	Contract No. 2 — 1906–1907 †Daily av. cu. yds.	Contract No. 11 — 1909–1910 Total cu. yds.	Contract No. 11 — 1909–1910 †Daily av. cu. yds.
Feb.	.....	....	37	....	492	19	.....	....	.....	....
Mar.	.....	....	.....	....	319	13	.....	....	.....	....
Apr.	.....	....	4314	173	5272	211	2537	101	2509	100
May	2	....	12812	512	12935	517	3573	143	7211	287
June	181	7	13048	522	13164	526	3742	150	6638	267
July	2432	97	19360	774	7778	311	2674	107	3909	156
Aug.	5321	212	15098	604	12476	499	5488	220	5062	202
Sept.	6497	260	16171	647	8482	339	3806	152	3581	143
Oct.	5252	210	16665	667	6724	269	4246	170	2292	92
Nov.	3636	145	8708	348	4053	161	2726	109	107	4
Dec.	308	12	2812	112	688	27	296	12	11	....
Jan.	110	4	808	32	236	9	244	10	*262	....
Total	23939	....	109833	....	72619	....	29332	....	31582	....
Daily Ave.	July to Nov.	185	April to Dec.	484	April to Nov.	354	April to Nov.	144	April to Oct.	180
Maximum days Work	251 cu. yd.		969 cu. yd.		605 cu. yd.		289 cu. yd.		432 cu. yd.	
	Tramway System		Cableway System		Cableway System		Cableway System		Cableway System	
CONCRETE PLANT	6—Ransome Mixers 1—Haines Mixer and 1—Cableway after Nov. 1st, 1905 *Misc.* 3—Foote Mixers		2—Haines Mixers 3—Cableways *Eastern Mixer* 2—Foote Mixers *Misc.* 4—Foote Mixers		2—Haines Mixers 3—Cableways *Eastern Mixer* 2—Foote Mixers *Misc.* 4—Foote Mixers		1—Haines Mixer 1—Cableway		1—Haines Mixer 1—Cableway	

* To balance final estimate.

† Daily average based on 25 days work per month.

Table No. 3. Concrete Work. Comparison of Progress on Contracts 1, 2 and 11

FILTER MATERIAL

Contract No. 1. The filter gravel was specified to be furnished in four sizes and placed on the concrete floor of the filters in the order and to the depths stated below:

No. 1 Gravel—3 in. to $1\frac{3}{4}$ in.—5 in. deep.
No. 2 Gravel—$1\frac{3}{4}$ in. to $\frac{5}{8}$ in.—$3\frac{1}{2}$ in. deep.
No. 3 Gravel—$\frac{5}{8}$ in. to $\frac{1}{4}$ in.—2 in. deep.
No. 4 Gravel—$\frac{1}{4}$ in. to coarse sand—$1\frac{1}{2}$ in. deep.

The filter sand is placed over the No. 4 gravel to an average depth of three feet.

Both the sand and gravel used for filter material was obtained from the bed of the Allegheny River, adjacent to the work, by the ordinary sand diggers which separated the gravel from the sand and deposited it in barges which were towed to the main dock and unloaded by means of derrick and clam shell bucket. The mixed gravel was then carried by the tramway and emptied into the upper end of the gravel screens, previously mentioned.

As the gravel was pushed along within this revolving tube by means of paddles it was washed by jets of water from a pressure pipe parallel with the axis of the screens, and passed through the various sized screens to the receiving bins below.

The screens were so arranged as to remove, first, the No. 4 or fine gravel, second, the No. 3 gravel, third, the No. 2 gravel and finally the No. 1 or coarse gravel was discharged out of the end of the tube.

This gravel screening plant was unsatisfactory from the start. The heavy or large sizes of gravel dragged the finer gravel along with it and thus the separation into the required sizes was incomplete. Furthermore when the screens were revolved at a more rapid rate to increase the output, the separation of sizes was less perfect. Much if not all of this trouble could have been prevented if the gravel plant had been arranged as a series of concentric screens with the coarser in the center so that the coarse gravel would be removed first and the fine gravel last.

Notwithstanding the defects in this plant, the Contractor

later, when he realized that greater capacity was necessary, exactly duplicated the former plant. The imperfect work of these screens made it necessary to provide fixed inclined screens with washing facilities at increased cost, on the outlets from the distributing bins and the amount of improper material thus removed, see Fig. 15, is sufficient proof of the ineffectiveness of the gravel screening plant. The transportation of the gravel from the distributing bins to the filters in hopper cars drawn by mules was reliable even if slow but it possibly could have been done more expediously and at less cost by means of trains of cars operated under electric or steam power.

Fig. 15. Debris accumulated in four days by re-screening No. 1 and No. 2 Gravel prepared by Filter Gravel Plant

The specifications for filter sand required it to be clean with an effective size of from 0.28 to 0.36 mm. and contain no particles having a diameter greater than 0.5 mm.

The plant for the preparation of filter sand furnished satisfactory material from the start, although a large percentage of sand within the contract requirements was unnecessarily wasted during the washing process. The early effectiveness of this plant was undoubtedly largely due to the foresight of the Contractor in first building an experimental washer and thus learning the methods for efficient and economical handling of this problem.

The sand when lifted from the river barges was dropped into an elevated receiving bin on the dock from which it passed through a revolving cylindrical screen which removed all gravel and allowed the sand to drop into the sand washing tank. This tank was about eight feet square and eight feet deep with a false bottom consisting of a perforated plate supported about 12 inches above the bottom of the tank. Water pumped into this lower compartment by means of a centrifugal pump passed up through the perforated plate and the sand above, and overflowed a waste weir at the top. The upward pressure and velocity of the water not only washed out all dirt and fine material but also kept the sand in suspension and uniformly varying from coarse sand at the bottom to fine sand at the top. By the opening of gates or ports in the side of the tank, sand of the required size and cleanliness was drawn off into a bin from which it was removed and placed in elevated bins by means of an inclined conveyor. From these bins the sand was transported by the tramway to a bin near the gravel screens and later conveyed to the filters as described.

The means for regulating the washing of the sand in the washing tank to suit the different grades of material supplied were inadequate and frequently over 30 percent of the sand was wasted over the overflow weir, 20 percent of which was within the requirements of the specifications.

The hopper cars for the transporting of the sand to the filters were not sufficiently tight to prevent a leakage of material as the cars were hauled along the tracks, and consequently the Contractor suffered a preventable delay and expense in removing this waste sand. Fig. 16 gives some idea of the amount of sand thus wasted.

One, if not the greatest, defect in the methods for handling both filter sand and gravel was the location of all the screening and washing plants on shore and in the midst of the work. This resulted in the digging, transporting and rehandling of much improper material at great expense to the Contractor which could have been almost entirely avoided if the sand diggers on the river had been fitted up to do the screening and washing.

This defect was not as serious as would have been the case if the Contractor had no other work but the supplying of filter materials, as he was able to utilize much of the sand and gravel unsuitable for filter materials in concrete work or in filling.

No start was made toward constructing the filter sand and gravel plants until the middle of the second season, 1906, and neither plant was ready to furnish satisfactory material until October 1906, or about $1\frac{1}{2}$ years after the award of the contract. The delay in starting upon this work was perhaps due to the slow progress on the filter concrete work, especially during the operation of the tramway system with its subsequent hindrance to the best operation of the cableway system.

Fig. 16. Contract No. 1. Filter Sand wasted from distributing cars and piled along the tracks

The placing of all filter material, amounting to 268 000 cu. yd., was completed in October 1908, with a daily average, based on 25 days actual work per month, of about 450 cu. yd.

During the same period of time the tramway from the dock to the central mixer handled approximately 70 000 cu. yd. of concrete sand and gravel, making the total daily average carrying capacity of this tramway approximately 560 cu. yd.

During February and March 1907 and February 1908 no

filter material work was in progress which if taken into consideration would change the above daily averages to 510 cu. yd. of filter material and 640 cu. yd. including concrete material.

Contract No. 11-H. The specified requirements for filter material are similar to those under Contract No. 1, except depth of sand in filters.

The Contractor for this work, benefiting no doubt from his knowledge of the plant and methods employed for furnishing filter material under Contract No. 1, simplified his plant and methods of work as already described. Practically all the screening and washing of the sand and gravel was done upon the boat, where an abundant supply of water was available at all times.

As the business of digging and preparing sand and gravel for various purposes is quite general in this locality a detailed description of the methods here used and as modified for this particular purpose, may be of interest.

The material brought up by the buckets from the bed of the river is first thrown upon grate bars spaced 5 in. apart which removes all large stones. At this point a 4 in. stream of water from a pulsometer pump, having a capacity of 600 000 gal. per 24 hours is played upon the material washing it into a cylindrical screening tube, $3\frac{1}{2}$ ft. in diameter. Through the center of this tube which is revolved at a rate of 14 revolutions per minute, is a 4 in. perforated pipe supplied with water under 35 lb. pressure which furnishes the second and final washing of the gravel on the dredge.

The first section of this screen is $4\frac{1}{2}$ ft. long and has 3/16 in. mesh, which removes the No. 4 gravel and sand. Outside of this screen is a screen with 1/8 in. mesh which separates the No. 4 gravel from the sand. The sand is carried by chute to the sand washing tank similar in design to that used on Contract No. 1 and the No. 4 gravel is carried by a belt conveyor to the rear of the boat where it is dropped into wheel barrows and thus loaded into a barge. The sized and washed sand from the sand washing tank is lifted by buckets and by means of a chute loaded into a barge on the left side of the boat.

The second section of the main screen is 4½ ft. long and consists of punched plate with 1½ in. square holes. This removes the mixed No. 2 and 3 gravel which is loaded directly into a barge on the right side of the boat.

The third and last section of the main screen is three feet long, of punched plate with 3 in. square holes. This removes the No. 1 gravel which is loaded into a barge by means of a belt conveyor. All material not previously removed passes out the end of the screening tube and is wasted.

The capacity of the dredge as equipped is 4 barges of sand and 7 barges of gravel or a total of 1 000 cu. yd. in 24 hours, which, however, varies with the material met with. The loaded barges were then towed to the dock near Ross Pumping Station and unloaded into the receiving bins as already described.

Here the No. 1 and the No. 2 and No. 3 gravel is run through a 3½ foot screen, nine feet long with 1½ in. mesh which is revolved at 18 revolutions per minute, and in this way, dirt and fine material is removed. The No. 2 and No. 3 gravel is separated by passage through a similar screen with ½ in. mesh being washed by means of a one inch perforated pipe within the screen. After these processes are completed, the gravel drops into the distributing bins below.

The screening of material to obtain any particular size of gravel is dependent on:

The character of the raw material.

The dimensions of the screen openings, and particularly whether wire mesh or punched plate with square or round holes are used.

The speed of revolution of the screen tube.

The length of the several screens.

The amount and pressure of water used for washing.

Considerable experimental work along these lines should be expected before satisfactory results are obtained.

As the No. 1, 2 and 3 gravel is removed from the distributing bins into the cars by means of chutes, it passes over fixed inclined screens and there receives its final washing be-

fore being placed in the filters. The No. 4 gravel and the filter sand are not washed or screened after leaving the boat.

The average distance from the dock to the filters is about equal to that from the gravel screens to the filters on Contract No. 1 but the speed of travel is greatly in excess of that upon Contract No. 1 on account of using electric haulage. There is little or no waste along the tracks as was the case on Contract No. 1 and the filter material is uniformly superior in cleanliness and correct sizing to that furnished under Contract No. 1. This is undoubtedly due to the more efficient plant and a less number of handlings. It is also worthy of mention that the plant from the first day of operation was able to furnish satisfactory material of all classes.

At the time of writing we have but five months record for comparison of progress with that on Contract No. 1. During this period, 14 550 cu. yd. of gravel and 23 670 cu. yd. of sand or total of 38 220 cu. yd. of filter material has been placed. This on the basis of 25 actual working days per month gives an average daily output of 305 cu. yd. with but one electric locomotive for haulage against a daily average of 510 cu. yd. on Contract No. 1, where 22 mule cars were used for hauling material. On Contract No. 1, about four times the number of men were employed on filter material work, than have been needed on Contract No. 11-H.

CONCLUSION

The good and bad points in plant and methods are much easier realized and explained after the completion of the work, than before or during construction.

It should therefore be the policy of both the Engineer and Contractor to keep careful records of type of plant, methods employed, progress made and detailed costs of all items of work in order to intelligently estimate, plan and conduct future work.

[The discussion of this paper has been combined with the discussion of the paper on "Forms for Concrete" which follows. Editor.]

FORMS FOR CONCRETE

By J. D. Stevenson*

In the discussion on Contractor's Plant in the preceding paper Mr. Field has touched on the method of placing concrete and the plant used. This paper will deal in particular with the forms used in the concrete construction. As the writer has been more closely connected with the construction of the filtered water reservoir the paper will refer more to that work. However, except for the filter material and piping the reservoir is typical of a filter, and what applies to one does to a large extent apply to the other.

From a viewpoint of forms, concrete work can be classified into two general classes; monolithic concrete construction and unit member construction. Under the first is included concrete structures built in place, under the latter is included structures the individual members of which are molded in convenient places and erected later. It is the intention to confine this paper to the class first mentioned, or forms for monolithic construction.

In the building of the Pittsburgh Filtration Works there were used about 334 000 cu. yd. of concrete. This concrete varied from the heavy massive work in foundations for machinery, to the light structural concrete in walls and floor slabs, and from the straight away work on walls and floors to the more intricate work necessary for groined arch vaulting. The forms varied as greatly as the concrete due to the many different conditions under which work had to be performed and the work offered many problems in forms for solution.

During the three years of active concrete work many different engineers, superintendents, foremen, carpenters and laborers were affiliated with the work and in this way were

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*Formerly Division Engineer, Bureau of Filtration, City of Pittsburgh.

brought together many different ideas and experiences. The object of this paper is to describe the various methods used and the results secured rather than to give a description of the work as a whole. Some of the items may be rather elementary to one having just this experience, but may be of interest and instructive to many other readers.

MATERIAL FOR FORMS

Probably the first thing to consider in the building of forms is what material to use. The choice will be influenced very largely by the number of times the forms may be used. They may be constructed of wood or metal, the latter was used chiefly in conduits and piers or forms having curved or irregular surfaces, while wood was used in all classes of work and almost entirely in walls and structures having plain surfaces.

The kind of lumber is influenced greatly by the cost and supply. White pine lumber is probably the easiest worked and will give the smooth face essential to the best work. The pine will prove very expensive for ordinary work, and spruce, fir, Norway pine and some grades of southern pine are more commonly used. For braces and uprights the quality is not of great importance, there is a point, however, where an inferior grade of lumber is not economical, as the increased number of times a piece of lumber may be used and the lesser quantity due to greater strength will outweigh the savings in first cost due to inferior quality.

Kiln dryed lumber is not best as it will swell too much when wet, and green lumber is not good as it will not swell sufficiently to make the forms tight. The best quality is a middle grade or partly dry.

When the contract is large, comparable in size to the Filtration Works, it will facilitate the work to buy the lumber in the rough and mill it on the site. This will often save delay due to delivery, will save in cost, and the waste can be kept at a minimum.

The proper thickness for the lumber (this applies chiefly to the sheathing) is a question which varies greatly with the

Contractor. Curved and irregular shaped forms can be made more easily with one inch lumber, and where there is much cutting the waste is less. On the other hand if a form is to be used but once the loss in wrecking thin boards is much greater than will occur with thicker, and more uprights or studs will be necessary to support one inch sheathing than two inch. It was found more satisfactory in the majority of work to use 1.5 or 2 inch sheathing in preference to thinner wood.

The thickness and spacing of studs and braces is entirely a question of load to be carried, and can be easily proportioned to the particular piece of work.

DESIGN OF FORMS

It is advisable to have the form and braces designed by a competent man, as often the foreman or carpenter in the field does not have the knowledge or experience necessary. It is often the case that a piece of form work will be over braced, or by reason of inexperience the bracing will be so arranged as not to secure the maximum results from the minimum labor and material. Frequently also the forms are underbraced and give away during filling. All this can be best remedied with a design made by a competent man which can be done at a small cost.

Where the forms are used but once and wrecked it is advisable to have the joints between boards *V* shaped with the vertex towards the concrete, known as a beveled joint, as the boards can be removed much more easily and with less waste due to breakage than if a tongue and groove joint had been used; and if the lumber is not too green the joints will swell shut and be just as tight. For forms used a number of times best results will be had from tongue and groove joints. The tongue and groove tends to make the several boards act more as a unit and the force necessary to break the bond between the concrete and form, which is applied more or less on a single board, will not distort the face of the form as quickly as without this unit action. The alternate swelling and shrinking due to the wetting and drying will not cause the trouble in a tongue and groove joint that would be experienced in a beveled joint.

In the design of forms, it is of importance to look to their removal, as upon the speed of removing and the number of times forms can be used with the minimum amount of repairs, rests the economy of the design. The forms should be designed in as large sections as can be conveniently handled. In deciding size, the removal of forms will have a greater bearing than the placing, as the removing of forms must largely be done by hand, often in cramped places, while the placing or building will be in the open and can be facilitated by cableway or derrick. It will be found very difficult at times to break the bond between a form and the concrete without damaging the form. Often it was necessary to have as many as twelve men pulling on a block and falls and then the ribs pulled from the sheathing before the bond could be broken.

In forms to be wrecked, spikes and nails should be very sparingly used; sufficient nails to hold the form together is all that is required as the concrete will furnish all the pressure necessary to hold the sheathing to the studs. It will not then be necessary to use sledges and bars in wrecking, and when the forms are removed the lumber will be in much better shape and can be more economically worked.

The building of forms without nails has been tried. The studs were placed and the sheathing, consisting of six inch boards with tongue and groove joints, were placed as the work progressed. The experiment was on conduit and the advantage claimed was easy removal of forms and complete access to all parts during filling. The results showed delay in placing concrete due to waiting on the placing of the sheathing and a rough and very unsatisfactory surface after removal.

It is best to completely set up the forms, nailing just sufficiently to hold in place, and, if advisable, to remove certain parts to facilitate filling; they having been once fitted can easily be replaced.

SUPPORT OF FORMS

There are a number of methods for supporting the forms from the interior while filling; by means of wooden struts, bolts, concrete struts and wiring. A very satisfactory method

is the use of wooden struts and wire; the struts to maintain the proper distance and the wire to tie the forms together. The struts must always be placed where the sheathing is supported by a stud and the wire should loop to the stud; then by twisting the wire with a short bar, the forms can be drawn tight and held rigidly in place during filling. When the concrete has been placed to the level of the strut it can be removed and the weight of the concrete will then hold the forms apart. In first placing the struts they should be lightly nailed, the wiring will hold them in place, and they will be more easily removed.

On removing the forms the wires should be cut close to the concrete, the ends stoved in with a punch and the surface smoothed over. The finishing is the one point more or less open to criticism, as it takes considerable care to make a good job and unless the Contractor is watched this part of the work will be shirked and ugly rust streaks will deface the concrete. A great advantage in the use of wire lies in the fact that a form can be tied down to prevent floating and can be tied and cross tied at any angle. No. 8 wire will fulfill the requirements of most work.

When the space between forms is so narrow that the removal of the struts becomes a troublesome task, concrete struts can be used. Concrete struts are previously cast and placed in the same manner as wooden, and can either be broken with a tamper when the concrete is placed to the proper level, or if they have been cast with a water stop they can remain in the wall. The greatest difficulty is in preventing a void immediately under the strut. The breaking will do away with this possibility. Care must be exercised to avoid a water channel along the side of the strut.

Bolts are used in several ways. In one method a pair of bolts are screwed into a nut which is placed in the central portion of the concrete and when the concrete has partly set the bolts are removed, the nut being allowed to remain. The space which was occupied by the bolt is filled with grout. Another method is to fit the bolt with threads and a cap on either end. The cap screws on the bolt and extends about three inches into the concrete; the cap is removed and the bolt

allowed to remain. The latter is much more expensive than the first mentioned method. In large work involving the using of the same forms a great many times the use of the bolts is very satisfactory and the small nut lost each time is of little value.

The forms, in addition to the interior bracing, should be braced on the outside; this is generally accomplished by bracing to the earth or to adjoining structures. The number of braces and the size are points peculiar to each individual piece of work. This portion of the form work is probably more neglected than any other. Forms are either underbraced or the braces which are placed do not assist in the support. Often during the filling when a strain has been placed on the forms many of the braces will be found loose. The exterior bracing must be relied on for holding the form to alignment. On the Filtration Works alignment was necessary only within very liberal limits. Butt bracing is more secure than splices, the salvage will be greater and the cost of reworking the lumber less.

In building a structure in a number of lifts it will often be found advantageous to terminate each lift of forms in a short section, say three feet high. This section which is tied together by wires and securely held to the concrete by the bond can be left, upon removing the forms, as a base upon which to build the next lift.

COATING FORMS

Forms are covered, or coated, to decrease the bond between the form and the concrete and thus permit easy removal or to give the concrete surface a smooth finish. The latter is important in the case of conduits, where the friction loss is a factor.

Covering wooden forms with metal has a number of objections; it is an added expense and does not increase the life, as the metal readily breaks and tears when removing, and if the form is strained in the handling the metal covering makes it harder to put back in shape. The rents, although smoothed down, still have irregularities which will catch in the concrete and the next removing will leave them in far worse shape. If metal is necessary a complete metal form is more economical.

Painting the forms greatly facilitates their removal and also increases the life of the forms and makes them much easier to clean. The pores of the wood and the cracks are filled with the paint and the grout is thus prevented from entering. A satisfactory method is to coat the forms after cleaning with cold water paint and after they have been erected give another coat. This is particularly applicable to conduit forms and was used very satisfactorily on the By Pass conduit.

Forms were often oiled on the filtration work and for walls and roof vaulting was very satisfactory. Other dressings composed of various proportions and combinations of soap, paraffine, kerosene, etc., are used but are more expensive and more troublesome to prepare and apply, and have little advantage over oil, or cold water paint.

BUOYANCY OF FORMS

The tendency of a form to lift during filling will cause much trouble if not properly cared for. In a wall section which has considerable batter, a hook made of reinforcing steel, imbedded in the foundation offers an admirable arrangement to which to tie the forms, the tie being made with No. 8 wire.

Conduit forms and box forms are often loaded with pig iron, lead or other heavy material. As this is always more or less expensive and troublesome, the Contractor is liable to take chances by underloading. A form failing in this way is a very serious problem as it is impossible to force it back in shape without removing part, if not all of the concrete placed. Under this same heading comes the rolling of forms which applies more to conduits and is mostly caused by uneven filling, that is, filling higher on one side of the barrel than on the other. The best method of preventing this is by care in filling, to keep a uniform level on both sides of the barrel.

In trench work where there is sufficient depth the upward or side movement of forms can be cared for by bracing to the sides of the trench.

JOINTS BETWEEN MONOLITHICS

The placing of joints and the method of making joints is generally decided by the Engineer and often proper consid-

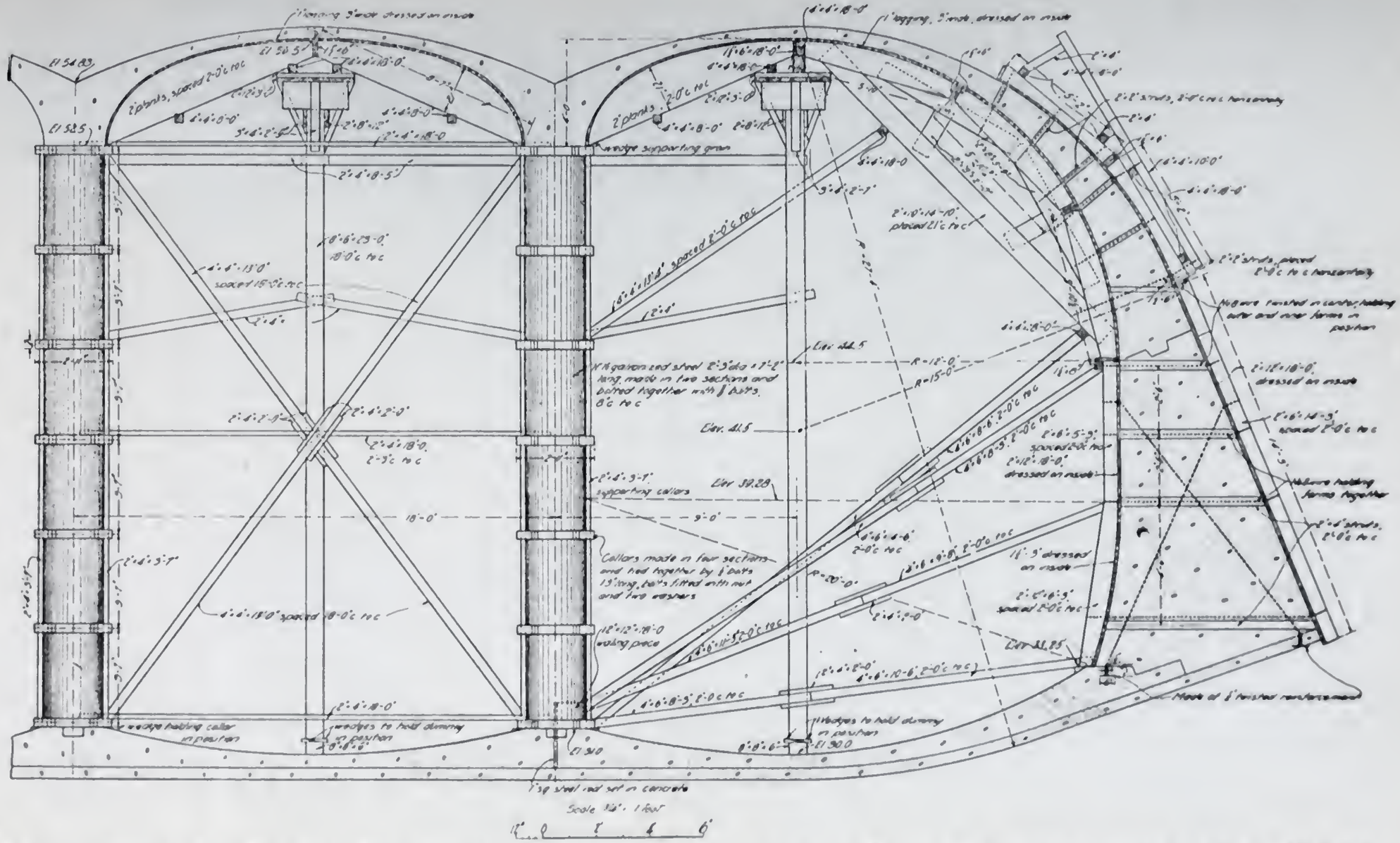

Fig. 1. Forms for Filtered Water Reservoir showing in Elevation Piers, Walls and Groined Arch Vaulting

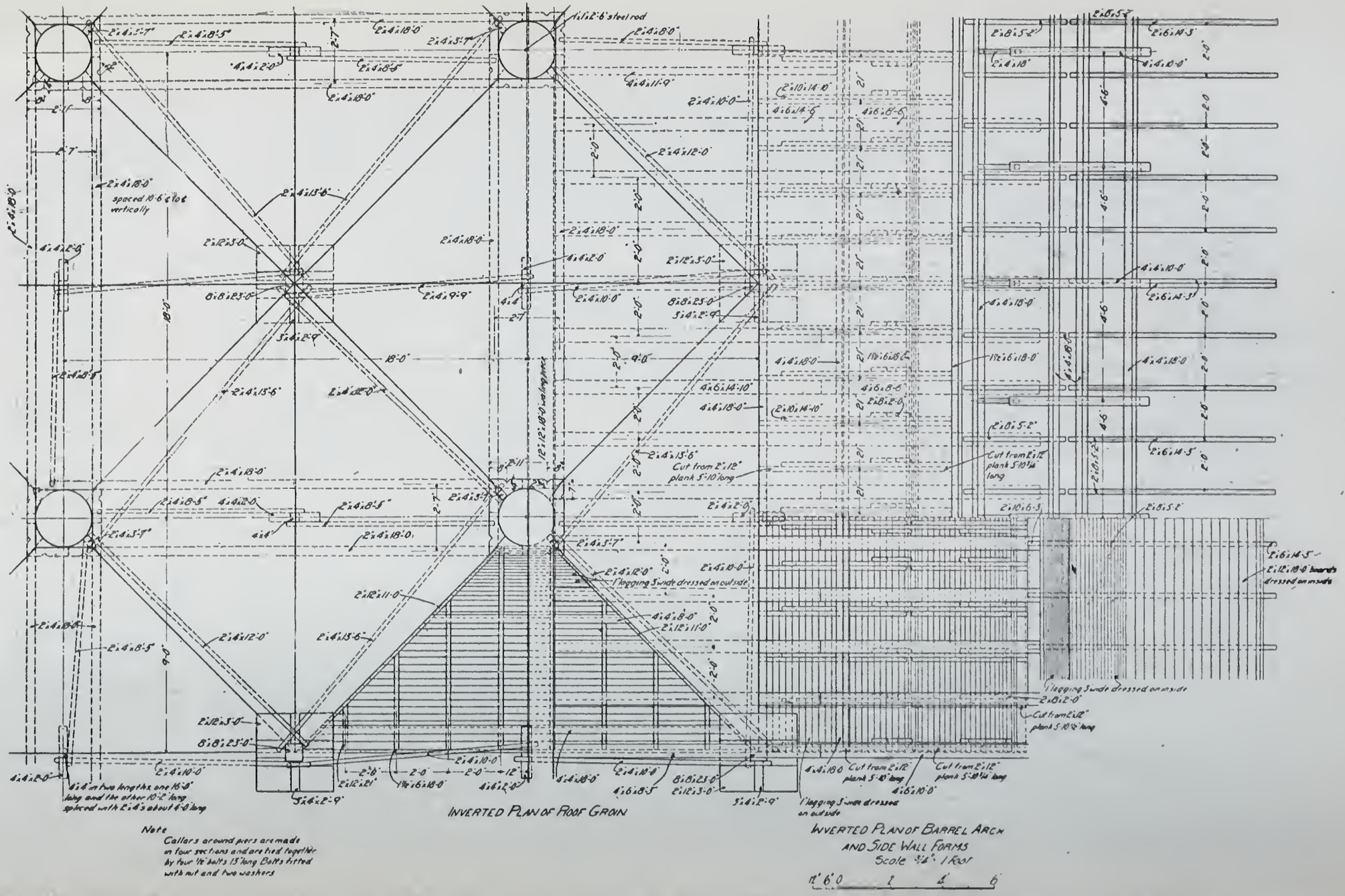
INVERTED PLAN OF ROOF GROIN
INVERTED PLAN OF BARREL ARCH AND SIDE WALL FORMS
Scale 3/4" = 1 Foot
Note
Collars around piers are made in four sections and are tied together by four 1" bolts 13' long Bolts fitted with nut and two washers

Fig. 2. Forms for Filtered Water Reservoir showing in Plan, Piers, Walls and Groined Arch Vaulting

eration is not given the Contractor in making the decision. The location of joints will govern to a large extent the possibility of cracks and thus is a large factor in the design of the work, and it may also greatly affect the cost of the form work and in this way the Contractor. A study from both the engineering and constructing point of view as to the effects of placing joints should be carefully made.

In the filtered water reservoir the location of joints was made after thorough study. The sides converge at the rate of one span of the arch in width, or 18 ft., in every nine spans in length. By this arrangement one set of forms could be used seven times, or practically the life of the forms. Referring to Figs. 1 and 2, the joints between sections of wall were placed directly over joints in the floor, joints in the barrel arch over joints in the wall and joints in roof groins were in line with joints in the barrel. Thus all joints were on center of bay lines, although all centers of bays did not have a joint, as often two bays, or 36 feet, were built monolithic. This located definitely the points to be affected by expansion and contraction and proper arrangement of keying could be made so as to prevent leakage. It also was the most economical design for the Contractor.

The design of a key between monolithic blocks varies a great deal. Some keys are to prevent slipping of one surface on another, while in other places the key is for water tightness. A key similar to a tongue and groove in lumber, the sides being slightly battered, is most generally used; it varies in size with the bulk of the structure. For vertical joints the groove will be constructed in the forms and is generally designated as a depressed key. On horizontal joints it will be found that a raised key, or the tongue, is more easily constructed for the reasons that the forms for it will not float, it is more easily held to a fixed location and removed, and can be cleaned better when placing the next section.

Keys of the tongue and groove type are not necessarily water tight, they only make the path to be traveled by the water longer and change the direction of travel.

For work requiring a large degree of water tightness a sheet of metal will give best results; sheet lead, copper, galvanized iron or similar metal imbedded three or four inches in one monolith, doubled back on itself and extending the same distance into the next monolith. The doubling back is for the purpose of allowing for movement due to expansion and contraction.

CARE OF FORMS WHILE FILLING

In filling forms the platform for mixing or dumping should be independent of the forms. This will prevent a shock caused by dumping. In no case should the concrete be dumped from a bucket directly into the forms, unless a bucket especially adapted to spreading is used, as this is likely to distort the forms and will often affect the uniformity of the finished concrete. By dumping a bucket on the platform the shock is taken up by the platform and at the same time the concrete will receive a mixing which will tend to remove any stratification which has occurred in transportation.

Before filling it is advisable to turn a hose on the forms, thoroughly wetting them. This will not only wash the foreign matter from the forms but will cause them to swell and prevent leakage. During the filling a carpenter should be constantly in attendance calking with cotton or jute any leaks and seeing that the braces are not loosened or disturbed.

Often trouble will arise in the removing of the struts, especially in thin walls heavily reinforced as the available room for the removal of the struts is small, and usually the forms and steel are covered with mortar, making a most disagreeable place in which to work. The struts should be removed as they are reached and careful watch kept so as to remove all.

REMOVING OF FORMS

The time for the removal of the forms cannot but be left to the discretion of the Engineer, as the time required for concrete to set varies greatly and largely depends on weather conditions and the particular brand of cement used, also the bulk of the structure will affect the removal. Often in cases of walls and structures requiring treatment of the surfaces to

produce a finish it is necessary to remove the forms at the earliest possible date and while the concrete is green. The question of length of time in cases of this nature can only be solved by previous experience.

Partly as an experiment and partly to facilitate the work, the forms for a few piers 20 in. in diameter, 8.5 ft. high, on the new filters were used twice in one day. That is, the forms were filled in the morning, removed and again set up and filled about noon; removed and again set at close of day ready for filling the first thing the following morning. The piers were not loaded for three weeks after casting. They have now been in use over one and one-half years and no trouble has been experienced. The general custom was, however, to remove the bracing from the forms the following day and to allow the forms to remain up seventy-two hours.

A schedule of time for removing forms under average conditions on the filtration work was as follows:

Floor forms	the following day
Pier forms	after the third day
Wall forms	after the second day
Vaulting forms on reservoir	after ten days
Vaulting forms on filters	after six days

Conduit forms varied from the following day to three days.

The work of removing forms is frequently, and unfortunately, placed in the hands of laborers and, as a result, the forms are broken and destroyed to the extent of costly repairs. In taking down forms the bracing or props should never be knocked out and the forms allowed to fall. This is not only liable to damage the forms, but the impact is liable to damage other work. The forms should always be easied down by a cable or other similar method. In roof vaulting the method of cable and drum described more in detail in another portion of this paper is very satisfactory. Sledges and bars should be used with the greatest of care, if at all. It will at times be very difficult to break the bond between the concrete and forms and the use of block and falls will be necessary. This will have to be done in a careful manner to prevent the twisting or distortion of the

form. It is well to start a form by use of a wooden wedge rather than exert a great force by block and falls.

The forms upon removal should be thoroughly cleaned of all cement. This can be done by scraping and will prove rather costly, but the thoroughness of this cleaning will greatly affect the speed of removal and the surface finish of the concrete in later work; so the additional cost spent in scraping is saved in other ways. It is much easier to remove the concrete which has adhered to the forms immediately upon the removal of the forms and the longer a form stands the harder it will be to thoroughly clean it. As soon as the forms are removed they should be cleaned and any necessary repairs made and the forms piled in some convenient place. The piling, although a small matter will often cause much trouble; if the forms are carelessly piled, having bearings at points that will allow them to sag, the forms are liable to set to this untrue shape and endless trouble in setting them to line and grades will be experienced.

STEEL REINFORCEMENT

There are numerous kinds and shapes of reinforcing steel, all claimed to fulfill some particular function in a reinforced structure. The point of interest here is the method of placing and holding in place, as upon this depends whether the constructed member will act as the designer intended.

There is no particular choice in the kind of a bar best to use as being easiest to hold in place, except that a bar having a twisted or irregular surface will hold without slipping, better than a smooth straight bar.

An example of a method of placing and holding steel can be presented in a brief description of the equalizing chamber built at the Brilliant Pumping Station. This chamber, 38 ft. deep, contained 445 cu. yd. of concrete and 20 000 lb. of steel or about 0.0034 percent reinforcement based upon the sectional area. Some of the walls were only 18 in. thick throughout the entire height. Fig. 3 is a photograph showing a view of this steel and Fig. 4 shows the form work.

The vertical rods in the walls of the chamber, numbering about 200 rods being for the most part one-half inch, were to

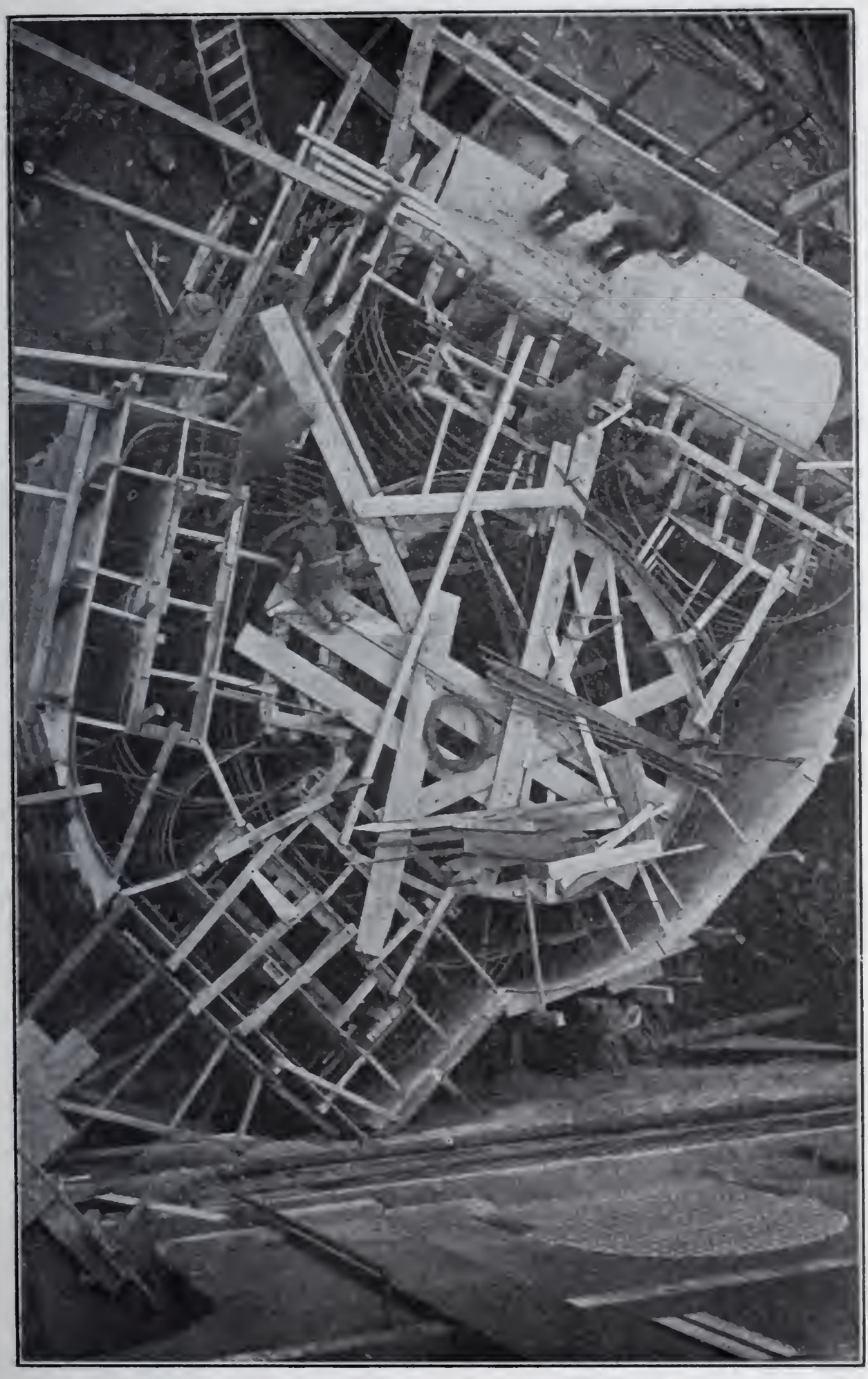

Fig. 3. Forms for Equalizing Chamber showing reinforcing steel

extend into the foundation sufficiently, 20 diameters, to develop the strength of the rod. Joints between successive days work were made at the level of the floor and to avoid having these rods extending up in the way of the form building and the necessity of supporting the rods at the top, which supports would be greatly in the way, bars 40 diameters long were placed one-half in the foundation concrete and one-half extending above the concrete foundation, to which, after the second lift forms were completed, were wired the vertical bars.

The inner and outer forms were wired together and spacers of wood used. The location of the wires was made with an eye to the placing of the reinforcement so that as many as possible of the vertical rods could be tied to the wires. The horizontal reinforcement, which was largely in the shape of hoops, varied from one inch to 0.375 inch, was tied to the vertical bars, and where possible laid on the tie wires. It was also necessary in several places to add 0.375 inch or 0.25 inch bars for support. This arrangement of steel proved very satisfactory. The test was very severe, as due to the narrowness of the space between forms the ramming affected the steel, and the removing of the spacers often necessitated a man using the steel as a ladder to go down in the forms.

The method used in the gate chambers was somewhat different. Here mostly horizontal bars were used. After the form was checked for trueness nails were driven in the side of the forms at the location of the bar. The bars were all cut and placed in racks easy for access. When the concrete was placed level with a nail a bar was laid in the concrete. This method involves close inspection and maintaining the concrete level to insure proper construction. In the floors and beams a similar method was followed; the bars were all cut and fitted, then laid to one side. A layer of concrete was placed slightly in excess of the distance from face to steel. The steel was then laid on the concrete and the bars tied together and the remainder of concrete placed.

In the equalizing chamber the steel required careful bending. There were twenty-seven different shapes. A record kept

by the writer on the bending of 10 325 lb. extending over a period of 10 days showed a cost of:

0.88 man hours per 100 lb. for blacksmith

1.66 man hours per 100 lb. for helpers

At the prices paid, or 25¢ per hour for blacksmith and 16¢ for helper this cost was 48.9¢ per 100 pounds. In addition to this was chargeable 0.24 man hours per 100 pounds for the layer out, which work was done by the boss carpenter at a cost of 20¢ per 100 pounds, the total cost being 68.9¢ per 100 pounds. In bending the steel a large platform was built and all shapes laid out full size, cleats were nailed at points of curvature and the rods bent to fit.

DESCRIPTION OF PIERS

Fig. 1 shows the form work for a 21.5 ft. circular pier 27 in. diameter, being one of 720 piers supporting the roof of the reservoir. The sketch is fully dimensioned.

The forms are in three sections each 7 ft. 2 in. long, each section consists of two semi circular pieces of No. 16 galvanized steel, flanged on the vertical edge, the flanges of the two halves being bolted together between two pieces of 2 in. by 4 in. lumber. The sections are clamped at top, bottom and middle point by a wooden collar made in four pieces and held by bolts.

The first intention was to make up the 7 ft. 2 in. sections on the ground and build them into place in the pier. About twenty piers were built in this way and proved very unsatisfactory, as the third points, or joints, were not rigid enough. The remaining pier forms were built complete on their sides and raised into place by the cable way.

The carpenters plumbed the forms with plumb bobs and the engineer corps checked the work with a transit. The piers were braced in sets of four, horizontally at top, bottom and center and cross braced from top to bottom. This allowed an unobstructed passage between the sets of four piers for the moving of the filling platform.

The removal of the forms was accomplished by removing all the collars and loosening all the bolts in the flanges, working from the top down. The lower section of metal was then re-

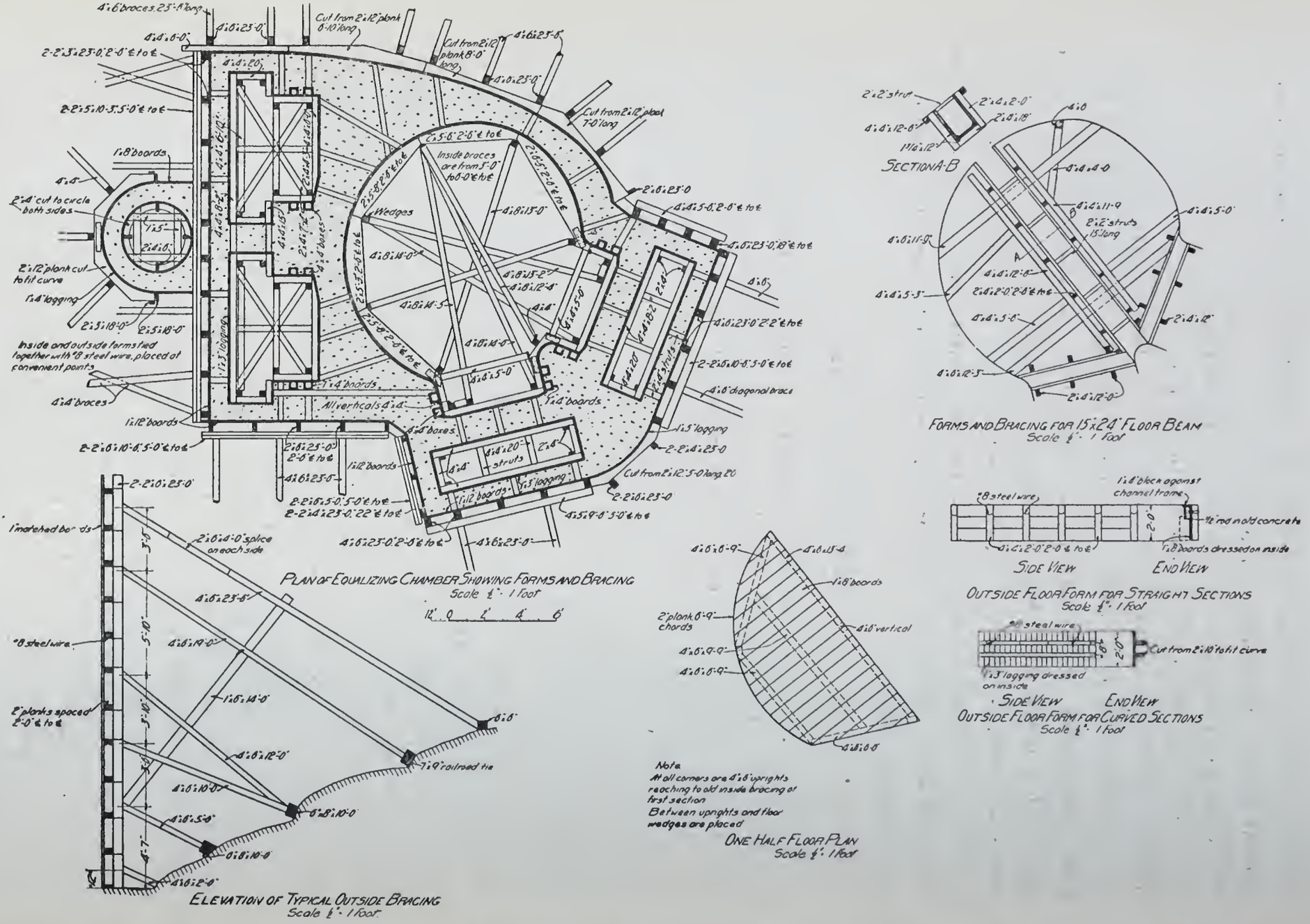
Plan of Equalizing Chamber Showing Forms and Bracing
Scale 1/4" = 1 foot
Elevation of Typical Outside Bracing
Scale 1/4" = 1 foot
Forms and Bracing for 15"x24" Floor Beam
Scale 1/4" = 1 foot
Section A-B
Outside Floor Form for Straight Sections
Scale 1/4" = 1 foot
Side View
End View
Outside Floor Form for Curved Sections
Scale 1/4" = 1 foot
One Half Floor Plan
Scale 1/4" = 1 foot
Inside and outside forms tied together with #8 steel wire, placed at convenient points
Wedges
Inside braces are from 5'-0" to 6'-0" c to c
All verticals 4"x4"
1"x4" boards
1"x12" boards
1"x5" logging
4"x6" braces
4"x8" diagonal braces
2"x12" plank cut to fit curve
2"x4" cut to circle both sides
#8 steel wire
7"x9" railroad tie
Note
At all corners are 4"x6" uprights reaching to old inside bracing of first section
Between uprights and floor wedges are placed

Fig. 4. Forms for Equalizing Chamber illustrating method of Interior and Exterior Bracing

moved and the upper two allowed to slide down the pier; the second was removed allowing the top to slide down and be removed. Thus a large amount of work was accomplished from the floor which saved considerable time. Before using the metal again it was thoroughly scraped and cleaned.

The metal and collars were renewed at intervals, in some cases they were used twenty times. The greatest trouble was caused by the indenting of the edges, permitting leaks which caused wash streaks in the surface of the piers. As the pier forms became older this trouble increased and it became necessary to calk with yarn around the bottom and at joints.

At first the forms were built to the neat required height and filled level with the top of form. The concrete when setting would shrink from one to 1.5 in. and it was found necessary to make the forms higher so as to allow for this shrinkage. It was then found advisable to build the forms to a greater height so that the finished pier would be one or two inches higher than required. This allowed the roof forms to butt against the pier and prevent lateral movement.

The pier forms contain 488 ft. of lumber and 688 sq. ft. of metal. The bracing contained 507 ft. of lumber.

The cost as compiled by the writer for form work on four piers is as follows:

			Rate per Hr.	Total Cost	No. Yd.	Cost per Yd
Stripping	Carpenter	13 hours	$ .25	$3.25	12.68	$ .27
Cleaning	Laborer	15 hours	.15	2.25	12.68	.18
Making	Carpenter	15 hours	.30			
	Laborer	15 hours	.15	6.75	12.68	.53
Setting	Carpenter	¾ hour	.30			
	Laborer	1¼ hours	.15			
	Cableway	¼ hour	.50	.95	12.68	.08
Plumbing & Bracing	Carpenter	15 hours	.30	4.50	12.68	.35
				17.70	12.68	1.41

This is an average from a number of observations taken at random and extending over a period of 8 months.

The piers in the last filters built were molded in a steel form which offered a great many advantages. The form was

very different from that used on the reservoir. They were used twenty times with practically no repairs, and were very easily and quickly removed and reset. In part of this work piers were built separate from the roof, the remainder were built monolithic with the roof. The piers built separate from the vaulting were braced from pier to pier at the top, a pair of rails were hung to the piers and on these rails were set kegs of bolts, which happened to be on hand, to load down the pier and prevent floating. The piers built monolithic with the roof did not require any greater loads than that furnished by the vaulting.

On the first filter beds the piers were square and built of wood. Fig. 5 shows the design of these pier forms. They were all built monolithic, with groined arch vaulting. The forms were used on an average of ten times and consisted of four sides held together by bolts, the removal of the bolts allowed the form to collapse.

BARREL ARCH

Figs. 1 and 2 show the design of what was known as the barrel arch form. This form was for that portion of the wall from the springing line of the arch to the center of the first bay. The inside shape was a quarter of a 12 ft. circle and the outside an arc of a 15 ft. circle. These forms caused more trouble than any others on the reservoir. The inside was built in three equal sections, each nine feet long and 5 ft. 10 in. wide on the chord. The ribs, 2 in. by 12 in., were placed on 21 in. centers and lagging was one inch by three inch, southern pine, tongue and grooved and dressed on both sides.

The outside forms were built in three sections, the first section being three feet of the wall form which was left wired to the wall when removing the back wall form; this gave a solid base upon which to build. The second was placed before filling and fastened to the inner form by wires and wooden interior struts and held on the outside by an out-rigging extending up from the wall. The third was placed after the filling had reached the top of the second form and was wired to the inner form.

The remainder of the arch or a little over one third of it was screeded, no form being used on the outside.

Some trouble developed after the third using and was entirely due to the manner of removal. The bracing extending from the top to bottom, shown in Fig. 1, was not removed and the forms were not taken down in three sections, but the entire form was removed at one time. The method of removing was to hitch a set of falls to one of the upper corners to break the bond and at times twelve men broke the rope before the form left the concrete. It was not uncommon to pull off several ribs in an attempt to break this bond. The result was that this pulling greatly distorted the form. This first showed up in the inability to make a good joint between forms and finally necessitated rebuilding the forms. The trouble could have been eliminated by removing the forms in three pieces rather than in one.

The barrel arches on the filters, Fig. 5, were similar, but one half the length. On these there was no particular trouble.

The barrel arch in filtered water reservoir contained 0.92$\frac{1}{3}$ cu. yd. per running foot and the units placed were 36 ft. long or 33$\frac{1}{4}$ cu. yd.

Lumber outside forms used 8 times=1100 ft.
Lumber inside forms used 8 times=3500 ft.
Lumber in bracing used 20 times= 700 ft.
Making at mill 240 hr. @ $ .35=$84.00 used 8 times=$ .31 per yd.

Taking down

1 foreman	2 hr.	@	$ .30=	$ .60	
9 laborers	18 hr.	@	.20=	3.60	
				4.20	33¼ cu. yd.=$ .13 per yd.

Hauling out

1 foreman	1$\frac{1}{3}$ hr.	@	.30=	.40	
12 laborers	16 hr.	@	.20=	3.20	
				3.60	33¼ cu. yd.= .11 per yd.

Cleaning and repairs

1 foreman	5 hr.	@	.35=	1.75	
4 carpenters	20 hr.	@	.30=	6.00	
2 helpers	10 hr.	@	.20=	2.00	
				9.75	33¼ cu. yd.= .30 per yd.

Placing					
Cableway	$\frac{1}{3}$ hr.	@	2.00=	.66	
Foreman	$\frac{1}{3}$ hr.	@	.40=	.13	
3 carpenters	1 hr.	@	.35=	.35	
5 laborers	$1\frac{2}{3}$ hr.	@	.15=	.25	
				1.39	33¼ cu. yd.= .04 per yd.
Trimming and trueing					
1 foreman	10 hr.	@	.35=	3.50	
4 carpenters	40 hr.	@	.30=	12.00	
2 helpers	20 hr.	@	.20=	4.00	
				19.50	33¼ cu. yd.= .58 per yd.
	Total cost				1.47 per yd.

The above cost is an average from a number of observations made by the writer. The cost of hauling out is rather high and unusual, the forms however were of awkward shape and very large, and had to be hauled on a truck by hand a distance as great as 300 ft. The floor over which they were hauled consisted of inverted groins with piers every 18 ft. The trimming and trueing at 58¢ a yard is due to the trouble previously explained in this paper.

WALLS

The wall forms shown in Fig. 1, are in accordance with the general practice in such work. All forms were made in nine foot sections and from top to bottom in one unit. The method for preventing the forms from raising is shown in the illustration and consisted of hooks set in the first layer of concrete and wires tying the forms to these hooks.

The forms were used on an average of ten times and the only repairs made were a board now and then, where the bar in removing had splintered or broken the forms.

The edges of the forms become more or less frayed and this was cared for by a metal strip tacked over the joint. This practice was permissible in this work as the face would not be exposed. In finished surfaces it should never be used, as the metal leaves a surface entirely different from the wood and very readily noticed.

The regular wall in the reservoir contained 2.33½ cu. yd. per running foot and as a rule the wall was built in 36 ft. sections

or 84 cu. yd. This amount varied within a yard as the point where the wall ceased and the barrel started was not closely defined.

Lumber in forms for one unit (used 12 times) 3600 ft.
Lumber in bracing for one unit (used 20 times) 2200 ft.

Time building at mill

Carpenters 110 hrs. @ $ .35=$38.50 (12 times)=$.038 per cu. yd.

Taking down

Foreman	10 hr. @	.35=	3.50		
2 carpenters	20 hr. @	.30=	6.00		
4 laborers	40 hr. @	.20=	8.00		
			17.50	84 cu. yd.	.208 per cu. yd.

Setting up

1 foreman	10 hr. @	.35=	3.50		
6 carpenters	60 hr. @	.30=	18.00		
4 helpers	40 hr. @	20=	8.00		
			29.50	84 cu. yd.	.350 per cu. yd.
Total not including cost of material					.596 per cu. yd.

The above cost is a weighted average as in this work there was a great amount of variance. Often the cable way was used in removing forms and the cost cut down, then again the forms would be in bad shape and require much repairing. As an example on the

21st wall forms cost	$	.73	per cu. yd.
23rd wall forms cost		.53	per cu. yd.
24th wall forms cost		.55	per cu. yd.
25th wall forms cost		.42	per cu. yd.
26th wall forms cost		.49	per cu. yd.

GROINED ARCH FORMS

Figs. 1 and 2 show groined arch forms in elevation and plan. Each pier top was molded on forms built in four triangular sections, the joints between sections being on centers of arches and on diagonal lines between piers. The ribs were two inch white pine placed on the diagonal line and on two foot centers between the diagonals, the decking was one inch southern pine tongue and grooved. The forms were well oiled before filling.

The pier edge of each form rested on a collar bolted to the piers. The piers, having been built two inches higher than the springing line of the arch, prevented any horizontal movement in the form. The four corners were supported by 8 in. by 8 in. posts and midway between corner posts were placed 4 in. by 4 in. posts. The proper elevation on the top of arch was first secured by placing wedges between the top of post and form. Later it was found that dumping the concrete disarranged these wedges and their use was discontinued and 0.5 inch boards were used and toenailed. This allowed only an adjustment of 0.5 inch, which was considered close enough.

The joint between forms on the top was made by a crown strip which varied from two to four inches wide. The corner joints were finished by a one inch triangular strip which relieved the rough corner. The forms being square and piers round required a filler in the corners. This filler was first made of plaster paris mixed with excelsior, but was unsatisfactory as the breakage was high and it was impossible to use them a second time. The cost of the filler in plaster paris was about 27¢ each. Later wood was used and the work was finished using wood. On Contract 11 the Contractor used a metal filler cut from No. 16 guage sheet iron. This filler was used over and over, the first cost being 10¢ each.

Figs. 5 and 6 show the forms used in filter work which are very similar to those of the reservoir. The roof and pier were placed monolithic in this work.

The method followed in placing forms was to first erect the shoring on the piers, then by cableway erect the corner posts and brace them to the piers. The arches were then lifted by cableway and placed in position resting on the piers and the corner posts. Most of this work was done at noon, in the evening, or on Sunday as at these times the cableway was not in use on the concrete. A crown strip was placed between the forms on the top so as to allow adjustment. This strip had to be ripped from boards and was done by hand requiring considerable time.

Removing the forms on the reservoir was done by means of a cable allowed to slip over a drum placed on the roof, a hole

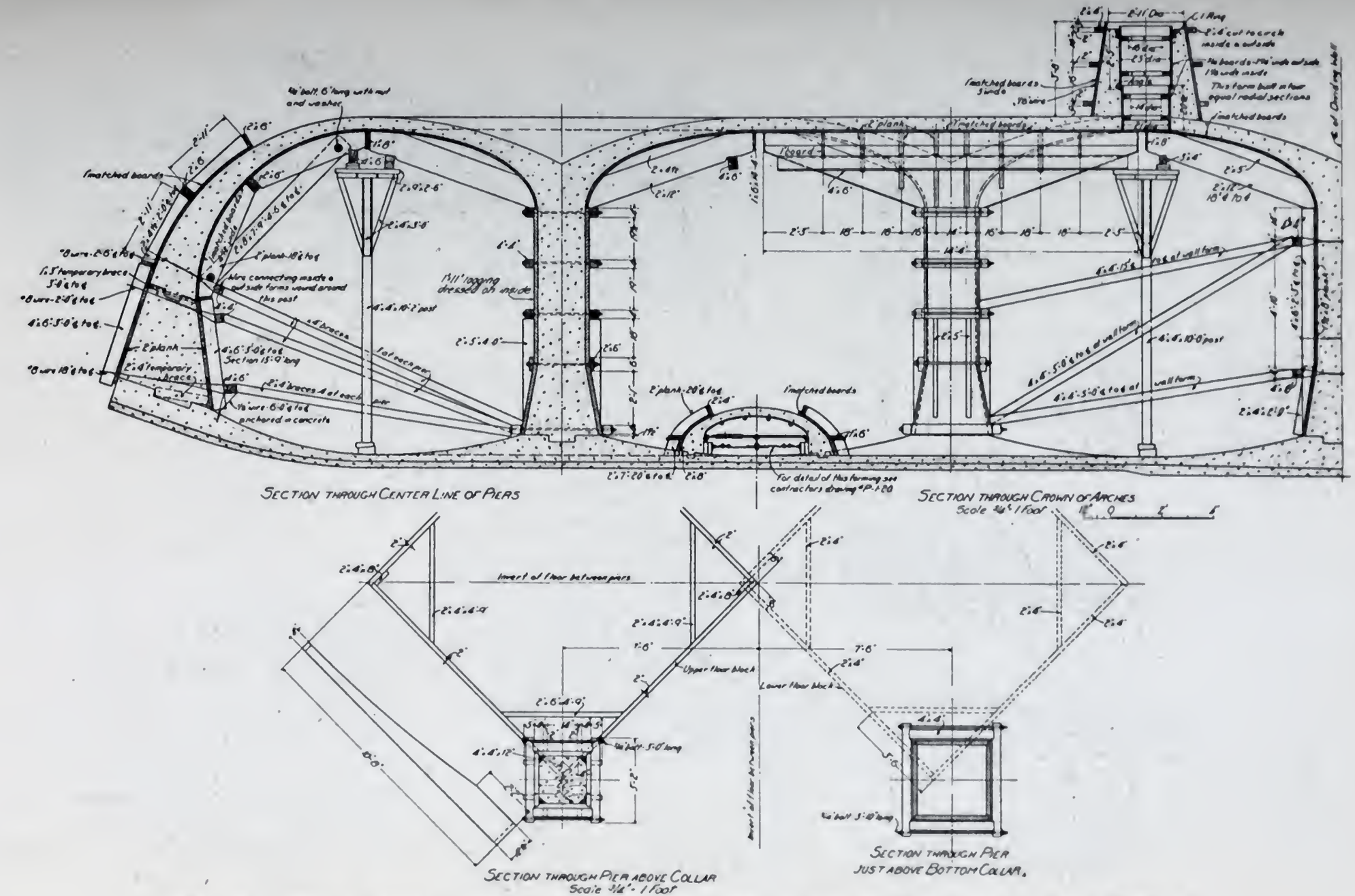
SECTION THROUGH CENTER LINE OF PIERS
SECTION THROUGH CROWN OF ARCHES
Scale 3/4" / Foot
SECTION THROUGH PIER ABOVE COLLAR
Scale 3/4" - 1 Foot
SECTION THROUGH PIER JUST ABOVE BOTTOM COLLAR.
Upper Floor block
Lower Floor block
Insert of floor between piers
matched boards
1"board
2"plank
For detail of this forming see contractors drawing #P-120

Fig. 5. Cross Section thru Filter showing Pier, Wall, and Groined Arch Forms

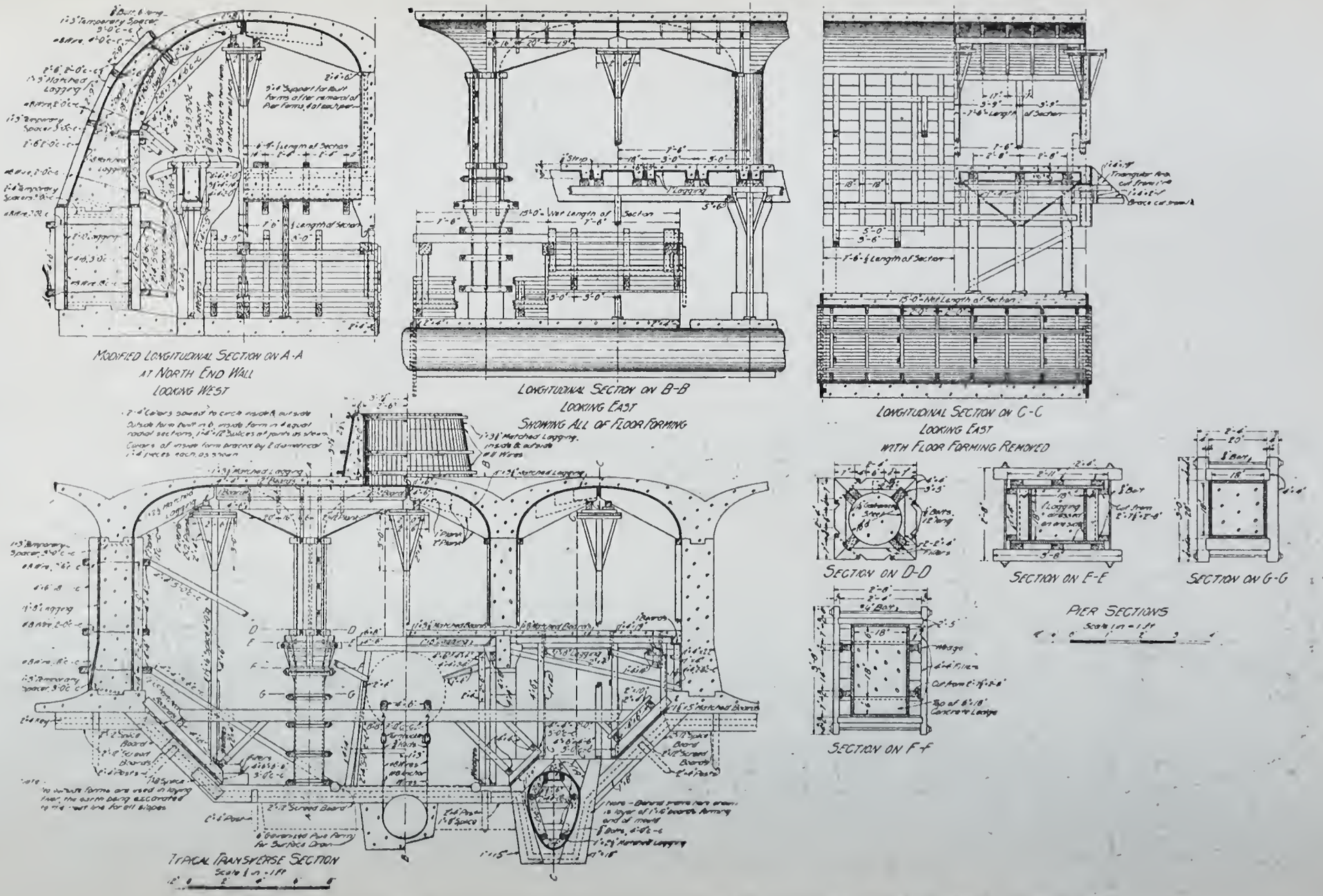

Fig. 6. Cross Section thru Filter Gallery showing Forms and Bracing

having been left in the concrete over the center of gravity of the form. It was necessary to resort to a set of blocks and falls to break the bond between concrete and forms.

In placing the concrete in the vaulting some trouble was experienced in securing the proper thickness. The concrete from the sides would occasionally work down into the center over the pier. This trouble was experienced in Columbus, O., where in place of six inch thickness they found only two inches of concrete and a test was made on one of the weakest arches. A load of earth was placed to the depth of four feet, when cracks developed in a vertical plane passing through two piers and a deflection of 13/32 in. was recorded. The work was remedied by placing a patch on the upper surface four inches thick.

This same trouble was encountered on the Pittsburgh work to a lesser extent. The maximum occurred where in place of 7.25 in. we had 4.75 in. of concrete. The error was discovered in 10 sides out of the 64 first placed and was remedied by patching, and further trouble of same nature was prevented by using a screed board at right angles to the line of piers instead of on the diagonal as had previously been used.

On Contract No. 1, the filters, the total amount of arch centering placed was 2 130 012 sq. ft. There were 240 000 sq. ft. of forms actually made to complete the work, an average of ten times use for each form. The actual cost was $0.0435 per sq. ft. placed; this cost includes plant charges, administration charges, material, etc.

On Contract No. 2, the reservoir, there were placed 243 390 sq. ft. of vaulting forms and there was actually made about 20 000 sq. ft. The cost was $0.096 per sq. ft. placed, or about $3.50 per cu. yd. of concrete placed. This cost is a final cost including everything chargeable to the forms.

For a detailed cost the following was prepared from information gathered by the writer:

Four forms made one pier top or 8.1864 cu. yd.	
Lumber in one pier top	1000 ft.
Lumber in posts and bracing	400 ft.
Lumber in shoring on piers	150 ft.

Making of groins at mill					
120 hrs. @ $ .35=$42.00			(12 times)		$ .42 per cu.yd.
Setting groins					
1 foreman	¼ hr. @	$ .35	.09		
3 carpenters	¾ hr. @	.30	.225		
6 laborers	1½ hr. @	.20	.30		
1 cableway	¼ hr. @	2.00	.50		
			1.115	(8.16 cu. yd.)	.14 per cu. yd.
Setting corner posts					
Cableway	1/10 hr. @	2.00	.20		
3 carpenters	3/10 hr. @	.30	.09		
			.29	(8.15 cu. yd.)	.03 per cu. yd.
Intermediate posts					
3 carpenters	1½ hr.@	.30	.45	(8.16 cu. yd.)	.05 per cu. yd.
Shoring piers					
2 carpenters	3 hr. @	.30	.90	(8.16 cu. yd.)	.11 per cu. yd.
Trimming and trueing					
4 carpenters	3 hr. @	.30	1.20	(8.16 cu. yd.)	.15 per cu. yd.
Taking down groins					
1 foreman	1⅓ hr. @	.30	.40		
5 laborers	6⅔ hr. @	.20	1.35		
5 laborers	6⅔ hr. @	.15	1.00		
			2.75	(8.16 cu. yd.)	.33 per cu. yd.
	Labor cost				1.22 per cu. yd.

To the above cost must be added a charge for hauling the forms from the place of removal to the place of setting. This varied greatly and from observations cost 15 man hours per 100 ft. hauled.

GATE CHAMBERS

The forms for gate chambers throughout the work were more or less similar and the same principle in form work was used throughout. The structures were rather irregular in shape, some portions of the forms could be used twice, but the greater portion had to be wrecked and the lumber partly used in rebuilding. The greater portion of the forms were built of 1.5 in. southern pine lumber surfaced on both sides; the por-

tions plain in shape were decked horizontally and the portions curved or irregular were decked vertically.

The forms were wired together and the exterior and interior braced. The dumping platform was built independent of the forms.

The placing of reinforcement is explained in detail elsewhere in this paper. The first section was built to the sub floor level; the second to a point about three ft. above the top of the gates, and the third up to the floor level including beams. The floor slabs were placed later.

CONDUIT

The construction of conduit forms was governed greatly by the place they were to be installed and the surroundings. A conduit in a trench offers different requirements than conduit in the open. Fig. 7 shows six conduits and the forms used on each.

The inner form or barrel is generally first placed. This is held to the proper elevation by piers, or saddles, separately cast. and the tops set to grade. The steel is next placed and then the outer forms.

Care must be exercised to prevent the form floating or rolling and in filling the bottom. The bottom is sometimes cared for by placing grout tubes, or by simply smoothing up after the removal of the forms. In a number of conduits on the reservoir work a board was left off the outside forms just above the invert and through this opening the bottom was successfully filled by tamping. The filling of one side and allowing the concrete to run under and seek its level on the opposite side, thus assuring filling in the bottom, is rather dangerous practice as there is great chance of moving the inside form or barrel.

The By Pass conduit, shown in Fig. 7, is seven feet in diameter and about 1200 ft. long, built in 36 ft. sections, contained 48.8 cu. yd. and 3600 lb. steel per section, and was built after the roof of the reservoir was in place, the piers and roof being used to brace against.

The barrel was placed on concrete saddles and painted with cold water paint. The reinforcement was next placed and then

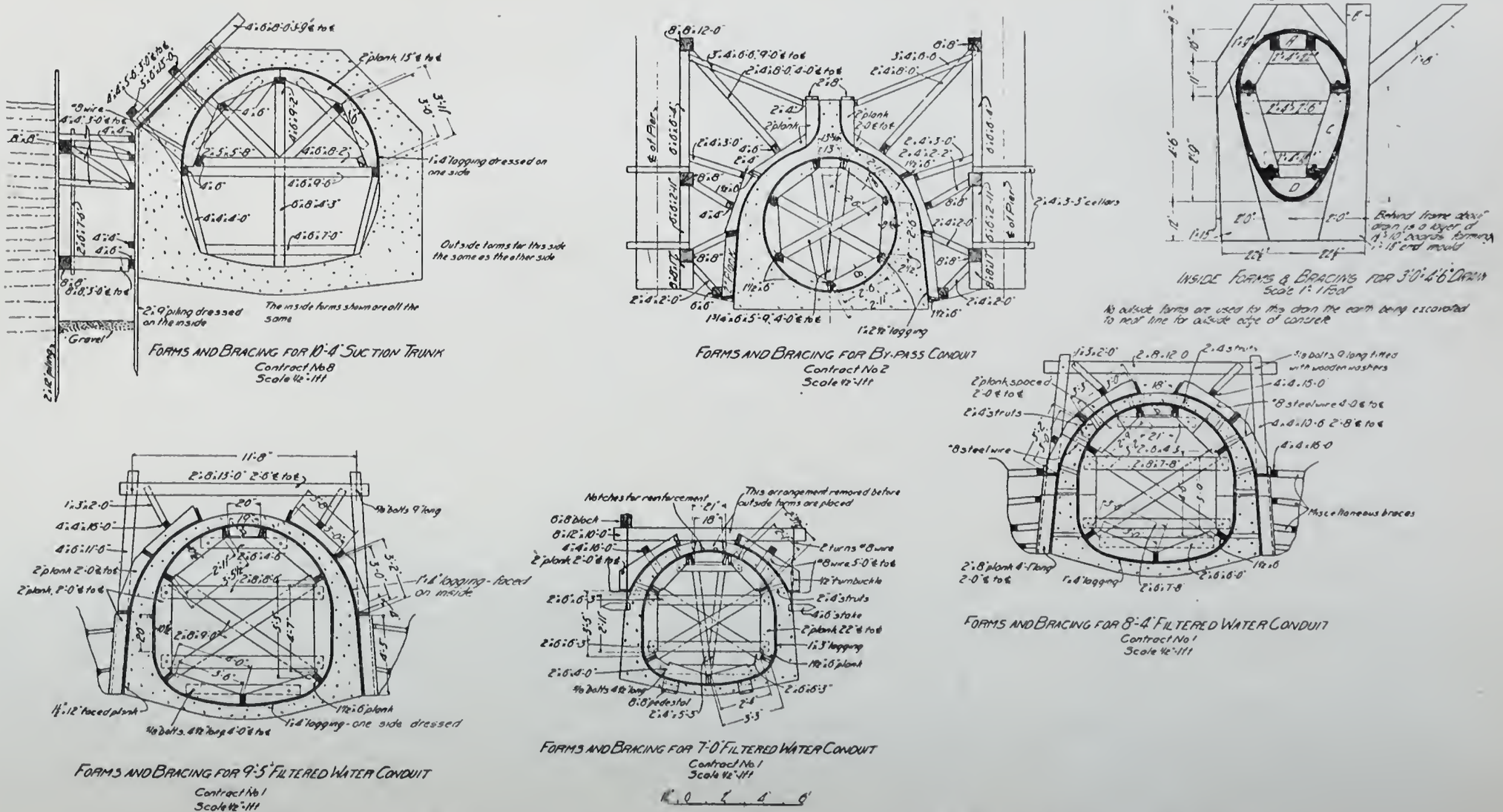
Outside forms for this side the same as the other side
The inside forms shown are all the same
Gravel
Forms and Bracing for 10'-4" Suction Trunk
Contract No 8
Scale 1/2"=1'-0"
Forms and Bracing for By-pass Conduit
Contract No 2
Scale 1/2"=1'-0"
Inside Forms & Bracing for 3'-0"x6'-0" Drain
Scale 1"=1'-0"
As adjacent forms are used by the time the earth being excavated to neat line for outside face of concrete
Forms and Bracing for 8'-4" Filtered Water Conduit
Contract No 1
Scale 1/2"=1'-0"
Forms and Bracing for 9'-5" Filtered Water Conduit
Contract No 1
Scale 1/2"=1'-0"
Notches for reinforcement
This arrangement removed before outside forms are placed
Forms and Bracing for 7'-0" Filtered Water Conduit
Contract No 1
Scale 1/2"=1'-0"

Fig. 7. Details of Form Work on the various Conduits at the Filtration Works

the outside forms. The braces were all fitted and marked and they together with all except the bottom outside form were removed and stored conveniently for easy access. The barrel was held down by braces to the roof and held laterally by braces to stringers placed along the piers. When the concrete reached the level of the top of the bottom form, the second form was placed and so on until the top was reached. After the concrete was placed to a depth level with the top of the barrel it was found that there was no tendency to rise and the braces to the roof were removed.

Trouble was experienced with the first three forms; they started to give during filling, but the knowledge gained in those mishaps was sufficient to show the weak points and work progressed nicely until a change of Superintendents placed a man in charge who decided to cut expenses, and the first forms built gave away. After that the work proceeded to completion without a mishap and the test showed up very satisfactory.

The forms in this conduit were all bolted together; the inside or barrel form collapses by dropping the top section. The time required to build one section was three days and the time to fill it was seven hours.

The forms including bracing contained 6350 ft. of lumber. The lagging was one inch southern pine and the ribs two inch white pine.

The cost of a 36 ft. section as compiled from a number of observations was:

	Time	Rate	Cost	Times used	Cost per yd.
Building forms at mill	489	$ .35	$171.15	10	$ .36
Carpenter work in field					
Carpenter	227¼	.35			
Helpers	19¼	.20	83.39	1	1.70

including taking down, placing steel, etc.

The forms for the seven foot filtered water conduit shown in Fig. 7 is a good example of form work for a conduit in a trench. In this conduit no outside forms except one on either side of the top was necessary. The sections were 30 ft. in length, contained 22 cu. yd. of concrete and 2660 lb. of steel. One foreman, four carpenters and four helpers took down the

back forms, set them up ahead and placed the steel ready for filling at the rate of one section a day. Two sets of forms were used and they were removed the following day as early as 10 o'clock: thus while filling one section another was being prepared. The cost of setting up the forms and placing steel was $1.15 per cu. yd. and the cost of bending steel 40¢ per 100 lb.

The 48 in. conduit was a plain circle inside with perpendicular sides and semicircular top outside. The drain was located in a 21 ft. fill, placed in sections varying from 20 ft. to 50 ft. in length and contained 0.387 cu. yd. of concrete and 35 lb. steel per lineal foot of conduit.

The forms were built in the mill and used six times in the field:

Lumber cost	.72 per cu. yd.
Mill Work cost	.30 per cu. yd.
Bending steel	.26 per cu. yd.
Carpenter work in field	2.13 per cu. yd.
Total	$3.41 per cu. yd.
Total	1.59 cu. ft. of drain

SPECIFICATIONS

A suggestion for specifications for forms is here given with the intention of stimulating discussion, from which a complete and more perfect set may be derived.

All forms shall be water tight, true to line and so built as to present a smooth surface, without indentations or warpings. They shall be strongly built, locked together, braced and rigid so as to allow a thorough ramming of the concrete without their being deformed or displaced until the concrete has set.

The forms shall be built in a thoroughly workmanlike manner and where necessary shall be coated to prevent the concrete adhering to the forms. The coating preparation shall be subject to the approval of the Engineer.

Beveled strips shall be placed in all corners where required to finish all sharp edges.

Wires or other method of holding the forms together, shall

upon the removal of the forms be cut off back of the surface of the concrete and the surface smoothed.

Blocks of wood or other forms of spacers shall be fastened, so that they will not be loosened and knocked into the concrete as the filling proceeds, and care shall be taken to remove them as the concrete is placed.

The space inside of the forms to be filled with concrete shall be thoroughly cleaned of all sticks, shavings and other materials not suitable to be incorporated in the concrete and the forms thoroughly wet before filling.

The time for removal of the forms shall be subject to the directions of the Engineer.

DISCUSSION

Mr. Morris Knowles: Many admirable descriptions of large public works have been published in engineering journals and in technical papers, but most of them seem to consider that the large financial problems of these public projects and the results to be obtained are the things which would engage the attention of the reader. It is rare that we have papers which deal so closely with the actual goings on as the work is being carried out, and I think it is excellent that we should have such information presented. You may call it the secrets of the trade, but I believe if we had more of such made public and sent broadcast, it would be very much better for everybody. It is true that in carrying on any large work the design is not the whole thing. Many other matters will have to be considered. There may be a great deal that looks good in design as a finished product, that is unnecessarily expensive or impracticable to construct by common methods of work.

There are two things I will speak of particularly. One is the question of sanitation and the other is the question of cost.

In regard to the first, you noticed upon one of the slides the contractor's camp at the easterly end of the plant. In the beginning of the work we realized that it would be a sad thing indeed if, in the carrying out of these works for the purifying of the city's water supply, we should ourselves

contaminate the existing water supply and produce an epidemic in the city. Contractors' plants are places where bad conditions and nuisances of all sorts proverbially prevail and where wastes are not taken care of. This made us think seriously about the problem and I think for the first time on any public work we included in the contract, and in detail in the specifications, provisions for the sanitation of the camps.

Some things have been done in this direction for a long time. Contractors have had doctors and quarters for temporary care of sick and injured, but generally it has been left for something to happen first and then some remedial action was undertaken. It is to the credit of the contractor that there was no epidemic, there was but little illness, there were few accidents, and things were taken care of very well. We had no undue rowdyism that is so usually common at labor camps. The subject matter of the articles which we introduced into the specifications have since been enlarged and extended by the New York Board of Water Supply in their contracts and upon other large works. But in the main the ideas have been carried out almost exactly, but with further and better provision that this sanitary work is allotted to a particular item or group of items and paid for as such as the work progresses. This is admirable because it makes the contractor realize that doing these things brings him back some money. Of course we are fast coming to realize that these things pay, outside of a humanitarian standpoint, because no man can carry on a large work unless his men are strong, able-bodied and healthful and unless accidents are few.

The other subject which I will mention in a general way, telling what we tried to accomplish, is the cost accounting system of the work. These data are of course beneficial, if for no other reason than that on such occasions as this details can be given, so that engineers can have the information, so that the contractor can have the information, so that the people can know, for guidance upon important public works. If discussions arise during the progress of the work as to extras, claims, etc., you have the data at hand, which will be accurate, and

which you can use as an aid in settling disputes which arise from time to time.

The methods we used may be somewhat open to criticism and I will be glad if others can suggest those which are better on a large and varied work, employing different classes of people and men of different minds. We had a central force account organization, with a man in charge and the clerks in the office and the field clerks obtaining the data. You will understand the distinction when I repeat, the central organization reported to the Chief Clerk and thus directly to the Chief Engineer, instead of having a separate force of accounting clerks upon each of the ten contracts, reporting to the division engineer in charge of that contract. The reason for the adopted policy is that some things, as administration, plant, materials and supplies, are general charges and a central organization could secure a better distribution than if it were endeavored to obtain at each individual contract, and we felt that in that way we would secure better results. It is open to the objecion that the man in charge of a particular contract may lose the close touch with this cost data to the disadvantage of not securing accuracy in detail. When he believes he alone is responsible, he will dig out things that a larger organization, or a central organization going about, will not secure, as they will not get into this intimate contact with things. The policy adopted may be open to some errors in that respect and I shall be glad to learn how others view this.

This central organization secured this data by going about at least twice a day and sometimes oftener. The inspectors themselves on the work had diaries in which they kept time account, material account, also the ordinary account of happenings like accidents and things of general interest. The man that went about had a card upon which he took down that information. He then posted that card on to a larger card, and these larger cards are posted once a week and once a month are posted on large sheets, on which the quantities are also posted. The clerk in going about secured the number of laborers and rates of pay, material, etc. The material is of course difficult to apportion, but so far as possible it was apportioned to those

works upon which it is used. At the same time these clerks secured the freight bills and the list of materials that came in, the account of the plant charges, such as cableways, derricks, cement-houses, shops, etc. They obtained the general charges of repair accounts in the shop, the staff charges of the whole administrative force, and office expenses, estimated in some cases as could best be determined. These large general accounts were not distributed from time to time and for this reason there was not of course the current knowledge of cost, except in the detailed way that Mr. Stevenson mentioned, viz, a current knowledge of the itemized cost without these general charges. Not until the end of the work was there a full and complete cost which included the distribution of these general charges.

A memorandum indicating the amount of these general charges may be interesting. In order to make the memoranda of cost given in tables No. 4 and 5, which follow, perfectly clear, it will be necessary to give a brief description of the main items included therein.

On Contract No. 1, the earth items, from 1 to 6, inclusive, comprise the excavation necessary, disposal of all the surplus material, and the placing in the embankments around the sedimentation basins and the filters and the filling over vaulting.

The concrete items, from 12 to 16, inclusive, and 18 to 21, inclusive, comprise the main items of concrete on the filters and the basins. The design of these various structures and the methods used in placing concrete, has been described in the previous paper and therefore these costs should be well understood.

For the arch centering, item 17, the contractor was required to build a certain number of forms, so that by using each form ten times the entire filter roof would be constructed, or a total of 213 000 sq. ft. of arch centering would be actually made, in order to complete 2,130,000 sq. ft. of roof.

On Contract No. 2, items 1 to 4, inclusive, comprise the earth items. Item 7 is the puddle over the reservoir roof, which varied in thickness from four to seven inches and is made in proportion of one part clay to two parts sandy gravel and thoroughly rolled and tamped. Item 8 consists of four inches of

Item	Description	Quantity	Engineers' Estimate	Bid	Unit Cost	Division of Unit Cost			
						Wages	Material	Plant	General
1	General Excavation,	589500	.27	.27	.44	.351		.061	.026
2	Excavation in Trench,	60800	.58	.65	1.02	.908	.037	.005	.065
3	Disposal of Surplus Material,	3000	.20	.15	.37	.351		.001	.016
4	Embankment, Class A,	128200	.15	.13	.16	.138		.013	.011
5	Embankment, Class B,	197500	.12	.13					
6	Filling over Vaulting,	253400	.20	.10	.14	.134		.004	.006
10	Broken Stone or Gravel Filling,	13480	1.00	.70	.53	.258	.20	.014	.054
11	Slope Paving,	18550	3.25	2.30	1.70	.463	.73	.273	.237
12	Concrete in Floors, A,	23640	6.25	5.25	4.89	1.506	2.18	.67	.536
12A	Concrete in Floors, B,	69760	6.50	5.25	4.27	.991	1.96	.633	.688
13	Concrete in Floors of Pipe Gallery,	10180	6.50	5.25	4.82	1.619	2.03	.524	.646
14	Concrete in Wall,	16560	6.25	5.25	5.50	1.955	2.17	.652	.722
15	Concrete in Piers,	10450	8.00	6.75	6.88	3.076	2.11	.82	.868
16	Concrete in Vaulting,	55790	6.25	5.25	4.23	.907	1.99	.501	.825
17	Arch Centering,	2130000	.06	.07	0.05	.026	.01	.002	.006
18	Concrete in Gate Chamber,	4230	6.50	8.50	7.95	3.283	2.54	.826	1.30
19	Concrete in Conduit not reinforced,	1290	6.50	8.50	7.01	2.953	2.15	1.006	.90
20	Concrete in Conduit reinforced,	9050	10.00	8.50	8.63	3.729	2.78	.974	1.146
21	Misc. reinforced concrete,	4110	9.00	8.50	12.65	7.107	3.00	1.003	1.545
22	Concrete in Trench,	3310	5.50	4.50	4.18	1.516	1.52	.438	.712
24	Steel reinf. in Conduits & Drains,	830240	.04½	.02¼	.03¾	.008	.017	.0001	.012
25	Misc. Steel Reinforcement,	608800	.04	.02¼	.02½	.004	.017	.0002	.002
111	Filter Gravel,	52300	1.15	1.00	1.22	.755	.20	.178	.092
112	Filter Sand,	215900	1.00	.85	.80	.286	.28	.158	.072

Table No. 4. Cost of Main Items on Contract No. 1.

Item	Description	Quantity	Engineers' Estimate	Bid	Unit Cost	Division of Unit Cost			
						Wages	Material	Plant	General
1	General Excavation,	117900	.20	.30	.43	.270		.109	.048
2	Excavation in Trench,	2720	.60	.70	1.04	.902	.008	.005	.121
3	Embankment,	159500	.25	.25	.37	.236	.066	.039	.032
4	Filling over Vaulting,	19560	.25	.30	.45	.425	.001	.006	.018
5	General Fill,	17940	.10	.12	.03	.018		.001	.015
7	Puddle,	4560	2.00	1.75	1.55	1.083	.135	.183	.145
8	Gravel Fill,	3430	.60	.50	.60	35	.200	.01	.037
9	Gravel on Revetment,	7380	.35	.50	.75	.458	.200	.04	.050
10	Timber Piles,	1140	.60	.40	.92	.663	.12	.073	.066
11	Timber Footing,	20.4	50.00	40.00	111.69	72.659	27.901	6.409	4.723
12A	Concrete in Floors,	12900	6.50	5.40	4.66	1.232	1.849	.536	1.040
13	Concrete in Walls,	9260	7.00	5.40	5.35	1.666	2.209	.542	.938
14	Concrete in Piers,	2480	8.00	6.40	7.12	3.42	2.029	.646	1.029
15	Concrete in Vaulting,	6180	6.50	4.70	3.80	.892	1.881	.488	.543
16	Arch Centering,	243390	.10	.08½	.099	.059	.024	.002	.014
17	Concrete in Gate Chamber,	1580	7.00	7.00	8.33	2.361	2.149	.55	3.272
18	Reinforced Concrete,	2090	9.50	7.00	8.20	3.51	2.639	.753	1.298
19	Concrete in Trench,	185	6.00	7.00	8.61	4.591	2.617	.716	.688
20	Concrete in Revetment,	3670	5.50	7.00	5.50	2.022	1.767	.671	1.042
22	Steel Reinforcement,	157800	.05	.02¼	.02⅞	.008	.017	.0001	.002
24	Misc. Reinforcement,	20750	.03	.02¼	.02½	.006	.017	.0002	.002

Table No. 5. Cost of Main Items on Contract No. 2.

gravel, which was graded and laid on top of the puddle. Item 9 consists of two feet of clean gravel placed under the revetment. Items 10 and 11, timber piles together with footing timber at the foot of the revetment, this work was required to be placed below the water level, which explains the rather high cost. The remaining items, 12a to 24, are the concrete items and have been explained in the previous paper.

The total plant charge on the nine contracts was $343 000, or 6.5 percent of the cost of the work. The staff and administration charge was over $700 000. The total of general charges to be distributed to this work, costing over $5 000 000 was about $1 000 000. or 20 percent of the whole cost.

Mr. Emil Swensson: Mr. President, I have listened with interest to the detailed descriptions of the Pittsburgh Filtration plant, as described by Mr. Field in his paper on Contractors' Plants and by Mr. Stevenson in his paper on Forms for Concrete, and would be glad to comply with your request for some remarks on these papers, if it were not for the position of arbitrator, which I occupy on this filtration plant. It would hardly be proper for me to discuss anything in connection with this particular plant, but I will make a few general remarks on the subject of contractors' plants in general and especially as discussed by Mr. Field in the introduction to his paper.

I most heartily agree with both the authors, and also with the remarks of Mr. Knowles, that in as much as engineers are required to make up nearly accurate advance detailed estimates of cost of the several works they are called upon to design, as well as to make the most economical design, they should be in position to collect, and should actually collect, as much detailed data as to cost of work, the execution of which they are supervising, as possible, and also study and analyze the plant and methods employed by contractors in their work, so that they can assume and consider the best probable plant and methods that a good contractor may use on any work that they design. Too many engineers either are not in position to gather and obtain such data on the work they supervise, or they neglect it, mostly from want of time, with the result that the opinion

often expressed by contractors—that engineers are not practical—has some foundation. However, many contractors show by faulty choice of plants and methods that they as often lack practical judgment. It would undoubtedly be of advantage, both to engineers and contractors and those that pay for the work the former design and the latter execute, if engineers and contractors would get somewhat closer together and have a full understanding as to the nature of the work, the plants required and the methods to be employed for the most satisfactory and economical execution of the work.

Even though the engineer must fully understand the best and most economical plant and methods that the contractor ought to employ in the execution of a particular piece of work, and design in accordance therewith, it is of the greatest importance for him to studiously avoid either showing any part of the contractor's plant on his drawings, or prescribing or even mentioning any methods of execution in his specifications. The drawings and specifications must confine themselves solely to what is required and wanted to make a satisfactory structure and must rigorously exclude the contractor's plant and methods for accomplishing the required results. Wherever this rule is not adhered to, the contractors invariably manage to so construe or handle the matter that extras are the result. Extras are a temptation to the contractor, the bane of the engineer and the fear of those that must pay the bill for the structure.

Referring to Mr. Stevenson's paper, I would ask Mr. Stevenson to explain by what method the contractor succeeded in forming the crown of the barrel arch, where the outside form stopped, without it becoming too thin at the top and slushing out over the outside form at its upper point, and also how the contractor kept the concrete from sliding down in the depressions over the columns in forming the groined arches.

Mr. J. D. Stevenson: The top portion was put in very dry and was well tamped.

Mr. Emil Swensson: Then you did permit the contractor to put in the concrete very dry?

As a contractor I have lately had similar experience, but

where the engineers insisted upon having all the concrete equally wet, with the result that, to keep the thickness of the arch at the crown to figures called for, the concrete at the point where the outside forms stopped became a good deal thicker than required, thus wasting concrete on every arch.

Mr. D. H. Littell: What means were used in making the joint in the successive portions of the concrete floor of the filter beds water-tight?

Mr. J. D. Stevenson: The floors in both the reservoirs and filters were built double. First we placed a six inch layer of concrete, on top of which was placed the diamond floor forms, lapping the joint about six inches with the bottom layer. The upper floor was about the curve of an inverted parabola.

Mr. D. H. Littell: Does that take care of the leak?

Mr. J. D. Stevenson: On the roof of the reservoir, they allowed the joints to remain just as they would occur in the forms, and on top the concrete was placed a layer of puddle, the layer varying in thickness from three inches at the edge to nine inches at the center sloping toward the edges so that the water would run to the edge. On top of the puddle was placed a four inch layer of gravel and in this was imbedded two inch agricultural drain pipe with open joints. These drain pipes ran to the side and connected with open joints in the top of two cast iron drains, one on either side of the reservoir. In the filters the water was allowed to accumulate in the pockets and run from the pockets through pipes down into the filters. As the water in the filter was to be filtered, the rain water was not objectionable.

Mr. Emil Swensson: In the introductory remarks in the paper of Mr. Field on the responsibility of the contractor he says: "The plant and methods of operation should be fully determined before completing the bid and these matters should receive most careful and serious consideration." This is, of course, very true but it becomes very interesting from the fact that the engineers asking for bids never provide sufficient time for the contractor to comply therewith. The time given the contractor

for figuring up his bid is invariably so short that the "most careful and serious consideration" of his plant and methods of operation, that is required for the execution of the work, can not be given and thus the bid is usually made up from general data based on previous experience or what he had learned of others doing in executing similar work, and only after he has become the lucky or unlucky contractor, as the case may be, has he time to work out carefully and seriously his plant and details of his methods. Very often he has not even time to give as careful and serious consideration to the execution of his work as would be best and most economical for his work, owing to the short time given him for its execution.

This has resulted in many contractors proceeding on what is known as "bulling the work through some how or other," which I interpret to be to get started at once to obtain immediate results, usually proceeding on one man's judgment rather than planning and studying it out on paper and with careful calculations; thus letting conditions meet him as they come up from time to time during the execution, rather than to anticipate the conditions and provide for them in advance. Such methods necessarily include errors in judgment, which must be corrected from time to time and thus incur unnecessary expense. This is the most common cause for contracts being finished at a loss instead of at the expected profit.

I am glad to say that of late signs for a betterment in this direction have been very frequent. Contractors are beginning to realize that a thorough study, planning and calculating of a piece of work to be executed, before starting actual operation, is of value to them. In a word, that engineers are really of some account. They are beginning to learn that a thorough consideration of all conditions to be met, both probable and possible, is of vastly more importance than to make the "dirt fly" at the earliest possible moment after signing the contract.

That a thorough study of conditions in making detailed plans, with some attending greater consumption of time, than a hasty execution of detailed plans, with the smallest consumption of time, will in the completion of the work produce a great saving of time as well as economy in cost of execution over the latter,

was forcibly brought to my attention nearly twenty years ago, when two bridge shops had the execution of the same amount of elevated structure of the same system. One of the bridge shops made a special effort to standardize every member of the structure, as well as the details of same, and the other detailed span for span, with little effort at standardizing. The former meant, of course, that the work of detailing fell upon one man when the latter did their work by a greater number of men, each one working on a span more or less independently. The result of these two methods was as follows:

The former did not order material from the mills so quickly or have the detailed plans finished so early as the latter, but the former finally had less drawings to make, less templets to make and the shop executed the work in shorter time and at less cost than the latter.

That this is also true of other classes of engineering work is illustrated by conditions to be found on the new Catskill Aqueduct, now being constructed in New York State. It is about ninety miles long and, of course, is divided up into a great number of contracts, which are naturally planned differently by the different contractors and their organizations.

On this particular work there are to be found so many different methods of procedure that a study of contractors' plants and methods all along this piece of work is one of the most interesting, to both engineers and contractors, of which I know at the present time.

I am personally familiar with two sections of this work, the work of which is done by the same contractor but under different organizations and methods; one by the old-time strictly contractors' method, on which the man in charge carries on the work entirely on his individual judgment and "in his head", as the saying goes; getting immediate results, changing plans and methods as the work progresses, letting the conditions meet him; and the other in charge of an engineer, who employs entirely the newer methods, laying out everything on paper, studying and calculating, contemplating probable and possible conditions to be met, and, in consequence, not obtaining immediate results; but good results when he gets them, having few changes

to make in plant and methods, with the consequence of surety in procedure and full control of all conditions. The difference in effect on the two pieces of work is very evident, even on hurried inspection, it being in every way in favor of the new or engineering method over the old or contractors' method.

It is, of course, of utmost importance that the engineering methods employed be based on a thorough study of both the successful and the unsuccessful "oldtime contractors" methods in order to produce satisfactory results, as a mere theoretical study, without practical experience, will produce as poor results as the execution of a contract without previous planning and study will do.

Mr. C. B. Albree: Not being a general contractor I am not in position to talk about details. But there is one point that was brought out very forcibly by Mr. Knowles that impressed me not only tonight but it has impressed me in the past, and that is that the system in common vogue of taking bids on the work. As a rule the lowest bidder, provided he puts up the bond, gets the work. In other words the fellow that guesses the lowest, in the old fashioned way Mr. Swensson suggested, gets the job and he generally gets left. It seems to me that in a big work like that, where contingencies will arise that cannot be foreseen, requiring changes in the plans and methods of handling the work, the risk should be taken by the city or corporation that is undertaking the work. Then comes a problem. You have got to have an honest contractor and you do not always get one by letting to the lowest bidder. It seems to me that a better way to handle contracts of this kind would be by what they call force account, that is, the payment of cost plus a reasonable percentage for the contractor's efforts. Of course, a great deal of work is done that way now, and as far as I know it gives satisfaction to both sides, where there is honest contracting. The benefit of bidding could be incorporated in that method by having the bidders state that they would do the work for cost plus a certain percentage, and he can vary that percentage, in his bid, 20 percent, 15 or 10. This gives the contractor who is up to date and has studied the job out, an opportunity to work

out better methods than the other man by which he can do the work and afford to get a 10 percent or 15 percent profit. Let the profit be the variable quantity and not the risk to the contractor.

I was talking to a contractor who has to do a great deal of work on the government dams. He told me that no one of the bonding companies would go on bonds for a river contract unless actual negotiable securities were put up with the bonding company for the full amount of the bond, and also that about 60 percent or more of the contractors on government work failed. One man figures on contingencies he knows are going to arise; the other one does not, and gets the contract and loses money. In view of what Mr. Knowles said tonight, based on an accurate cost account, and we heard his figures and there are all sorts of variations of actual cost over and under the estimate, it does not seem to me that the contractor ought to be responsible for that sort of work, and it seems to me the paper is more important in bringing this out than it is on the technical points, as an account of the carrying out of this particular contract.

Mr. L. C. Blum: I would like to ask Mr. Stevenson if he has any data as to how many times the same form was used in the work.

Mr. J. D. Stevenson: That will have to be answered in a general manner. Some forms stood more usage than others. As a rule the vaulting forms were used ten times. The contractor was required to make sufficient forms that in ten usages he would complete the work. The wall forms were used oftener than that. I think they were used fifteen and sometimes twenty times. The barrel arch forms were only used about eight times, and the pier forms 20 to 25 times.

The pier forms on Contract No. 11, which were especially well designed, proved themselves well adapted to the work and only a few of those forms were made. I am not mistaken, I think, in saying they were used 30 to 40 times. Probably Mr. Field can tell more about that than I can. There was very little depreciation in these steel forms. In the pier forms on the reservoir the trouble occurred in the edges of the metal.

The edges of the metal would be dinged in removing and although efforts were made to straighten them there would still be a little irregularity and when placing the concrete the liquor would run out and leave long wash streaks on the face of the concrete; toward the last of the reservoir work most of the joints were caulked. Caulking was also resorted to in the bottom of the forms, the first 18 inches or so of concrete was placed very carefully, after that the bottoms seemed to tighten themselves.

MR. D. H. LITTELL: I had a little piece of work for the government once myself. The specifications called for a vitrified cinder to be used in the concrete. We sent a sample of boiler house cinder which was rejected. We next got a sample of furnace slag, or clinker which was also rejected. They wanted a vitrified cinder. We did not know what vitrified cinder was and we wrote and asked if they would kindly tell us but they could not tell us. It ran along several months and the work finally got in shape to start when they notified us to send them on samples of our materials. Passing a small blacksmith shop one day I gathered up some of the cinders that were swept out the side of the forge, and sent them on. This was just what they wanted, and we went ahead with the work.

Another part of the specifications was on cement. It was specified to use either Alpha or Rosendale cement for reinforced concrete. At that time the Alpha Cement Co. was oversold and we could not get it. We sent a car of Sailor's cement down to start the work. The inspector, a very good engineer sent on from Washington, rejected the cement. We could use either Alpha or Rosendale but it must be one of them. As a matter of fact we had to ship the Sailor cement back and let the work stand two months before we could get Alpha cement shipped in. That is a sample of the red tape in government work.

MR. M. HOKANSON: As I had to do with the designing of forms of the various layouts for the contracts under discussion this evening I would like to add a few remarks in regard to the designing of forms. I want to say that the forms as used would today possibly be considered as not the very best that could be made. But at that time we made a study of forms

that had previously been used all over the country and we thought we had worked out the problem as well as on any contract previous to that time.

At the time the problem of using steel forms came up. These had not been used to any extent before, and as far as I know we were the first to experiment with steel forms for conduits. Since that time steel forms have been quite extensively used all over the country, particularly for work where great repetition occurs.

In regard to groined arches, I have not seen any steel forms used as yet, but I have no doubt that in the future such forms will be used even for that class of work, because there is undoubtedly a great advantage in steel forms. Lumber is getting more expensive and the life of wooden forms is rather short.

MR. B. A. LUDGATE: What proportions of cement, sand and gravel were used in the concrete in the various parts of the work, such as in the floors, pillars and roof.

MR. F. E. FIELD: Practically all the work, floors, piers and vaulting, was 1, 3 and 5. Some of the reinforced work was 1, 2 and 4 concrete.

RECENT RETAINING WALL PRACTICE,

CITY OF PITTSBURGH.

By Chas. M. Reppert, C. E.*

Introduction. It is proposed to discuss in this paper some of the retaining walls recently constructed by the Department of Public Works, Bureau of Construction, of the City of Pittsburgh, to review the methods used in their design and the assumptions upon which the designs were based, and to give data relating to costs of such structures.

Owing to the topography of this district the construction of retaining walls is frequently required. In municipal work very frequently a considerable portion of the amount expended on street improvements is chargeable to the construction of retaining walls.

Until recently it has been the practice to construct these walls of masonry and plain concrete. Such walls may be described as gravity walls to distinguish them from the reinforced concrete walls whose strength to a much greater extent depends upon the internal strength of the structure.

Most of the gravity walls that have been built by the City have bases ranging from $\frac{1}{3}$ to $\frac{1}{2}$ the height. Very frequently, however, they are carried to a considerable depth below that required by the earth pressure in order to reach the surface of rock or shale. In general most of these walls are doing good service and such failures as have occurred have been due to the most part to poor construction and lack of drainage.

During recent years the construction of walls of reinforced concrete has been resorted to. The stability of walls of this character depends upon the weight of the masonry, the weight

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*Division Engineer, Bureau of Construction, D. P. W., City of Pittsburgh.

of the superimposed earth resting on the back and heel of the wall, and the internal strength of the structure. In some designs the frictional resistance of the earth prism resting on the heel of the wall has been introduced as a force resisting overturning. Since, under certain conditions, the wall may fail without bringing this force into action, the writer is of the opinion that sufficient reliance cannot be placed on its action and the frictional resistance has therefore been disregarded.

Comparing this new type of wall with the old gravity type, the quantity of concrete is much less, but the cost per unit is greater. The foundations of the reinforced walls need not be carried to so great a depth since the foundations can be spread and the unit base pressure reduced. In municipal practice in this City, however, it is not possible, ordinarily, to extend the toe beyond the face of the wall since the structure must be within the street lines, and for this reason the economical design of walls is limited.

Further comparing the reinforced type of wall with a gravity wall and assuming that in each instance the resultant of the pressure cuts the middle third, the ordinary requirement for the gravity wall, the reinforced wall will possess a much greater factor of safety on account of its ability to resist internal strains and consequently to resist pressures that cause the resultant to cut the base outside of the middle third.

The question as to which type of wall should be built is for the most part a matter of economy. The location, the time available for construction and the character of the proposed contract under which the work is to be done will sometimes influence the decision as to which type should be built.

Cost of Plain Gravity Walls. The unit contract cost per cubic yard for concrete in gravity retaining walls may be estimated at from $6.50 to $7.00 per cu. yd. The cost of the excavation varies widely, depending upon the conditions and the method of disposition. The cost of reinforced concrete walls may be estimated at about $8.00 per cu. yd. exclusive of steel and excavation. Steel will cost from 3¢ to 4¢ per pound.

METHOD OF DESIGN, EARTH PRESSURE

Notation. The notation and formulae for earth pressure used in this paper are given in the following list: (See Figs. 1 and 2).

G = Weight of wall and earth.
h = Height of wall,
b = Base,
P = Normal thrust = $\frac{h^2\gamma}{2}\,\frac{1-\sin\phi}{1+\sin\phi}$
ϕ = Angle of repose,
γ = Weight of earth filling,
p = Equivalent fluid pressure,
P = Normal thrust = $\frac{1}{2}ph^2$
M_r = Moment of resistance to overturning for wall and superimposed earth = G a
M_t = Overturning moment of thrust for Normal thrust $M_t = \frac{1}{6}ph^3$
M_s = Moment of stability of wall = $M_r - M_t$,
C = Compression at toe,
Q' = Thrust developed by tipping of earth wedge = $\frac{K\gamma}{2}h$
Q = Thrust developed by sliding of earth wedge = $\frac{\pi}{8}h^2\gamma$
U' = Thrust necessary for overturning $\frac{1}{3}$ h from base.
U = Thrust necessary for overturning $\frac{2}{3}$ h from base.

The formula used for the determination of the lateral thrusts is in the form $P = \frac{1}{2}h^2\,\frac{1-\sin\phi,}{1+\sin\phi}$ in which P is the total normal lateral thrust, γ is the weight of the material per unit, h is the height, and ϕ is the angle of repose for the material. This formula which is commonly known as Rankines formula is based on the assumption that the earth is a granular mass without cohesion and applies to walls where the surface of the filling behind the wall is horizontal. The lateral pressure thus developed is termed the normal thrust to distinguish the pressures determined in this way from those determined by the other formulae applied for different loadings. The point of application of the normal thrust is $\frac{1}{3}$ the height of the wall from the base and only the horizontal component of the resultant is considered, the friction being neglected.

The equivalent fluid pressure is a unit weight of material that will produce lateral thrusts equal to those developed by the formula for the normal pressure. This equivalent fluid pressure is denoted by p. In determining the proper angle of repose to be used for the material ordinarily found in this location the following values of ϕ together with the equivalent fluid pressures for the different weights are used in a well compacted fill.

Wt. of material.	ϕ	p	Slope.
100	45°	17.2	1:1
110	45°	18.8	1:1
120	45°	20.6	1:1

For more severe conditions such as a new fill on a slope of clay, for shale sub-strata, or for a clay fill where good drainage cannot be effected.

Wt. of material.	ϕ	p	Slope.
100	33°42′	28.6	$1\frac{1}{2}$:1
110	33°42′	31.5	$1\frac{1}{2}$:1
120	33°42′	34.4	$1\frac{1}{2}$:1
130	33°42′	37.2	$1\frac{1}{2}$:1

Design of Retaining Walls
Method of Design

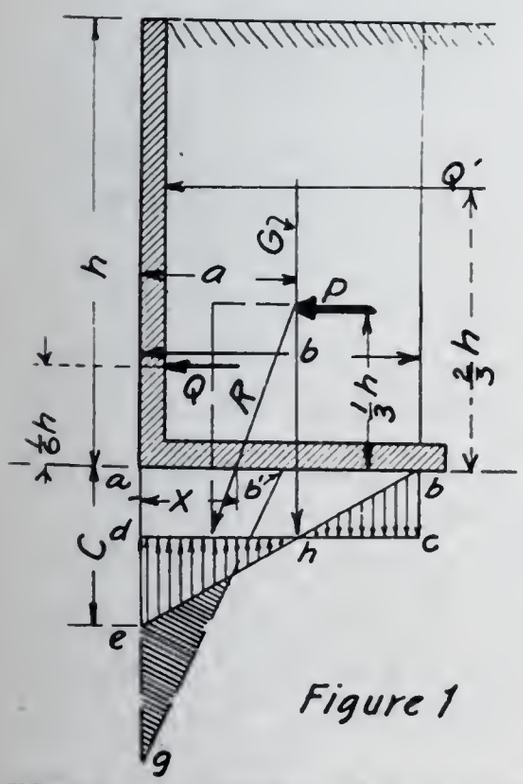


Figure 1

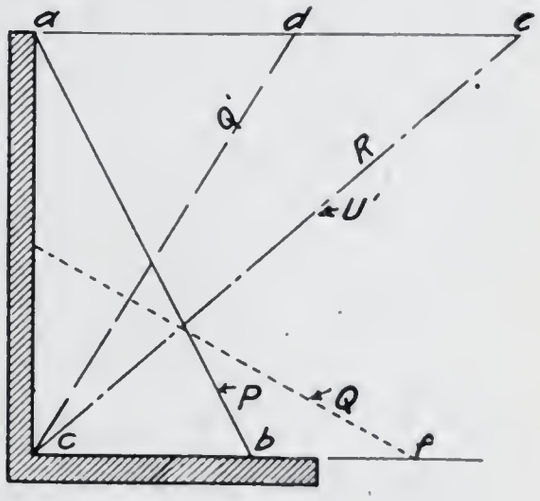


Figure 2

Figure 1. Design of retaining walls, method of design, illustrating forces acting and base reactions.

Figure 2. Design of retaining walls, method of design, graphic illustration of earth pressures.

For facilitating calculations the writer has prepared a diagram giving the value of the equivalent fluid pressure for different values of the angle of repose and different slopes. In the diagram a curve is plotted for each weight of material varying from 100 to 130 lb. per cu. ft.

It is a well known fact that the lateral thrusts developed by an earth fill are seldom, if ever, in accordance with the ordinary formulae used. It is frequently noted in excavations that the maximum pressures are developed at or near the top of the excavation. It has also been observed that where conditions are favorable that pressures exceeding that computed by Rankines formula are at times developed. It is necessary to make provision in some designs for these excessive pressures and also for additional thrusts developed by freezing of the filling in back of the wall, for slipping of the fill on inclined rock or clay surfaces, etc.

This aspect of the earth pressure problem was discussed by Mr. J. C. Meem in a paper, "The Bracing of Trenches and Tunnels, with Practical Formulas for Earth Pressures," read before the American Society of Civil Engineers.* In the discussion, Mr. E. G. Haines proposed two formulae, one for the determination of the pressures caused by the tipping or falling forward of the earth mass behind the wall and the other for the slipping of the mass. For the determination of such pressures this method of treatment appears to be the most rational and the method proposed by Mr. Haines has been used in these designs where the conditions seem to demand such provision.

For the tipping of the earth mass behind the wall the formula used is $Q' = \frac{k \gamma h}{2}$ = the resultant pressure developed by the tipping of the fill behind the wall. The maximum unit pressure at the top of the wall is equal to K, and the point of application of the resultant thrust is $\frac{2}{3}$ of the height from the base. In this formula γ is equal to the unit weight of the fill, h is equal to the height of the wall and K is a co-efficient varying with the height of the wall. For a 15 ft. wall, or h= 15 ft. K=4.1; for h=25 ft., K=6.8 ft.; for h=30 ft. K=8.2, etc.

* Trans. Am. Soc. C. E. Vol. 60, 1908, p. 1.

In working up the values of the co-efficient K Mr. Haines considered the arching thrust transmitted to the back of the wall by unit strips of the semi-circular mass, the diameter of which is equal to the height of the wall.

For the slipping of the earth mass against the back of the wall the formula proposed by Mr. Haines is $Q = \frac{\pi}{8} h^2 \gamma$, which gives the total resultant thrust developed. This formula for Q is developed by assuming that the earth mass behind the wall slips and that the surface of the fracture of the mass is semi-circular. It is further assumed that this semi-circular mass, whose diameter is equal to the height of the wall, revolves about its centre of gravity. Mr. Haines assumed that the point of application of the resultant was $\frac{5}{16}$ of the height of the wall from the base. It seems more reasonable, as suggested by Marsh and Dunn in their "Manual of Reinforced Concrete," to assume that the point of application of the resultant is 1/6 of the distance from the base, since the intensity of pressure at the centre of the wall is zero. The maximum intensity of the thrust developed at the base of the wall by this formula is equal to $1{\cdot}571 h\gamma$.

Briefly reviewing the subject of earth pressures it is obvious that the pressures to be provided for and their points of application will vary with the character of the materials and with the conditions existing. Where possible, test pits should be sunk, particularly where the wall is to retain an old fill. The character of the fill, however, is seldom definitely known in advance of the construction, so that too much reliance should not be placed in any formula. Where walls are constructed to retain clay fills, placed on inclined, or impervious slopes, it would appear to be good practice to make provision for possible slipping or tendency of the fill to slip. The writer believes that as the fill settles and becomes compacted that these pressures will decrease, hence high unit stresses have been allowed under some conditions. Under what may be considered the working loads the stresses have been held at fairly low values to provide for possible increases in the loading, and on

account of the fact that this type of construction is comparatively new.

Determination of Base for Gravity Walls. In designing gravity retaining walls and in comparing the resistance of reinforced concrete walls with gravity walls, it is convenient to express the value of the equivalent fluid pressure, under the thrusts developed by which, the resultant of the weight of the wall and the resultant thrust cuts the middle third of the base. The superimposed weight of earth is included in the weight of the wall. This method of treatment is outlined and discussed in Turneaure and Maurer's "Principles of Reinforced Concrete Construction."

For a width of top of wall of $\frac{1}{5}$ the base the relation is $b = \frac{h}{10.6}\sqrt{p}$. Where b is equal to the width of base, h is equal to the height of wall in feet and p is equal to the equivalent fluid pressure in pounds per cubic foot. Also $p = 112\frac{b^2}{h^2}$, M_r = moment of resistance of wall = $63.26b^2h$ and $M_t = \frac{1}{6}ph^3$.

For convenience in computing, the values of the relations of b/h for the corresponding values of the equivalent fluid pressure have been plotted under the assumption that the resultant is to cut the middle third of the base. A curve is drawn for each unit weight of fill and for each ratio of the top of the wall to its base.

DESIGN OF REINFORCED CONCRETE WALLS

In designing reinforced walls it is frequently of considerable assistance to compare the resistance of the proposed design with a gravity wall of given base in terms of the height. This comparison is particularly valuable when gravity walls have been built in the locality where it is proposed to construct the reinforced wall. Having decided upon the value of the equivalent fluid pressure under the thrusts developed by which the resultant is to cut the middle third of the wall, the overturning moment may be equated about the toe of the wall with the approximate weight of the proposed wall, the width of base being variable. In this manner the width of base of a reinforced wall

can be determined, having the same resistance under the normal thrust as the gravity wall with which it is compared.

Under loads exceeding the normal thrust the reinforced wall will have a much greater factor of safety owing to the ability of the structure to take tension. The stresses in the steel can be proportioned according to conditions so as to withstand much greater thrusts than could be resisted by the gravity wall. The stress in the steel is fixed so as to be at ordinary working values under the normal loading, with higher stresses under the other and more excessive loadings. If the full strength of the wall up to or approaching the point of overturning is to be developed then the stress in the steel at this point should not exceed the elastic limit.

In the upper portion of the wall the stress in the steel is generally kept at a lower value under the normal pressure so as to make provision for slips, the thrusts produced by the tipping of the fill and possible pressure produced by freezing.

In comparing the strength and stability of gravity walls with reinforced walls it is necessary to consider their relative strength under different conditions. In the gravity walls when the resultant cuts outside the middle third tension exists in the back of the wall and the stability of the wall will then depend upon the character of its construction. Any considerable amount of tension, however, would of course make the wall unsafe. Therefore, as a unit the reinforced wall on account of its ability to take tension gives a structure having a much higher factor of safety.

The gravity wall is better able to resist excessive pressures applied to only a portion of the wall, than a reinforced wall designed to resist normal pressures only, on account of the nature of its construction admitting of a better distribution of pressures. When the resistance of a gravity wall is exceeded by the thrusts, the wall in general fails slowly, while the reinforced structure would be more likely to fall suddenly, probably resulting in much greater damage. It is therefore essential in designing reinforced concrete walls to keep the stresses sufficiently low so as to provide for possible loads exceeding the normal pressure, however, under these excessive loads, such as

are computed in accordance with the formulae for Q and Q^1, the stresses may be at a much higher value.

The line of action of the various forces and resultant pressures at the base and floor reaction are shown diagramatically in Fig. 1. In this diagram the rectangle *abcd* represents the uniform weight of the wall and superimposed earth. The pressure triangle *abe* represents the upward pressure on the base of the wall under the normal thrust p. The triangle *hbc* represents the resultant downward pressures on the floor and the triangle *dhe* represents the resultant upward pressures on the floor. The reaction at the base under the thrusts Q^1 is indicated diagramatically by the triangle $ab'g$.

Fig. 2 shows diagramatically the thrusts applied to the front wall under the different loadings. By the use of a diagram similar to this, the loads being plotted in lb. per sq. ft., the strength of the front wall and ribs may be proportioned to withstand the conditions imposed.

Reinforced Concrete Data. The following is the data used in designing the reinforced concrete:

Modulus of elasticity of steel, 30 000 000.

Modulus of elasticity of concrete, 2 000 000.

Ratio 15.

Anchorage 40 to 50 diameters.

Shear without diagonal reinforcement not to exceed 40lb. per sq. in.

Computations for reinforced concrete sections by straight line formula. Steel in direct tension 20 000lb. per sq. in. Steel reinforcement used in the designs was square twisted rods of medium steel conforming to the Manufacturers Standard Specifications for such material. It was bent cold to the required shape shown on the contract plans.

DESIGN OF DILWORTH STREET RETAINING WALL

The Dilworth street wall was erected in connection with the grading, paving and curbing of Dilworth street. It was erected during the summer of 1909. In preparing plans for this wall comparative designs were made to determine the most economical type of wall. The site upon which the wall is built is a steep

inclined hillside, upon which an old fill about eight to ten feet in depth had been placed. This old fill was of conglomerate material, composed of clay, loam and also contained a large quantity of rubbish.

Test pits were excavated showing that shale of good quality was to be found at a depth of about $9\frac{1}{2}$ feet below the surface at the deepest section. The character of the material overlying the shale was such that it was deemed unsafe to construct a plain gravity wall without carrying the footing to the shale. The design of the gravity walls for comparison was therefore based upon carrying the footing to rock. The lateral thrusts, however, were computed for a depth of 33 ft. for the deepest section, which section was compared with the cost of constructing a reinforced retaining wall 35 ft. in depth at the same point; for the other depths the comparison and designs were made in a similar manner.

The character of the material used for the new fill for the proposed street was not exactly known but from an inspection of the locality from which the fill was to be taken it was supposed that this fill would be clay mixed with a small portion of shale. This assumption was correct.

In deciding upon the proper coefficient for computing the lateral thrusts to be resisted by the proposed wall, there was taken into consideration the fact that the clay filling would be placed upon a steeply inclined surface and underlaid with several feet of fill of poor character and that this material was underlaid by sloping impervious rock strata. It was therefore deemed advisable that the wall be constructed to resist a fill whose angle of repose ϕ would approximate 33 deg. 42 min. Further, on account of the nature of the material underlying the fill, it was considered necessary to provide an additional factor of safety for loads in excess of the normal computed loads. These excess loads might come from a slipping of the earth wedge of the new fill or from the tipping over of this wedge.

It is interesting to note in connection with the assumption as to character of the material and the probable lateral thrusts developed by it, that at the end of the wall where the embankment was filled out to the street line with a new fill, that

the bank slipped, the line of rupture being 10 or 15 ft. back of the top of slope and the toe of the slope rising up five or six feet.

Comparative Designs. The comparative designs made included tentative designs for gravity walls and for reinforced concrete walls of differing construction. Owing to the profile of the ground the wall was built in three sections of different depths. The reinforced walls consist of three sections, 35, 30 and 21.5 ft. in depth respectively. Beneath the floor of these sections it was proposed to construct piers running down to rock, thus saving a considerable quantity of concrete and excavation. The gravity walls were designed to extend to shale and were therefore of greater depth at the corresponding sections than the reinforced wall. In designing the walls, however, they were all subjected to the same lateral thrusts.

Estimated Cost. For plain and gravity walls the estimates were based upon the following estimated costs:

Concrete above footings.....$6.50 per cu. yd.
Concrete in footings.....$5.50 per cu. yd.
Excavation .....$ .75 per cu. yd.

For the reinforced walls the estimated costs were as follows:

Concrete in piers .....$6.00 per cu. yd.
Reinforced concrete ..... 8.50 per cu. yd.
Steel reinforcement .....$.04 per lb.
Excavation ..... $ .80 per cu. yd.
Structural steel .....$0.025 per lb.

Prices Bid and Contract Prices. The prices bid and the contract prices were considerably less than the above. The contract prices were as follows:

Plain concrete in retaining wall.....$5.00 per cu. yd.
Reinforced concrete .....$5.25 per cu. yd.
Steel reinforcement .....$.0275 per lb.
Structural steel .....$.035 per lb.
Excavation .....$.50 per cu. yd.

The actual unit costs of the work, which are given in Table 3 were somewhat greater than the contract cost and less than the estimated costs.

Design of Gravity Walls. The gravity walls were designed for $\phi = 33$ deg. 42 min., weight of earth 110 lb. and equivalent fluid pressure p=31.5lb. per cu. ft. Designs were made for three depths to correspond to the three depths for the reinforced walls as previously stated. For each section two designs and estimates were made. One for a base of .4 the height and the other for a base of .5 the height.

Proposed Gravity Wall, 35 ft. Section. This section has a total depth of 42.5 ft. from top of wall to base of footing. The wall is designed for a depth of fill of 33 ft. and the results obtained were compared with a design of the reinforced concrete section for a depth of 35 ft.

The dimensions of the gravity walls designed for this section are shown in Figs. 3 and 4.

Table No. 1 gives the results of this investigation. The wall with a base of .5h is designed so that the resultant of the lateral thrust developed with angle of repose, ϕ=33 deg. 42 min., will pass through the middle third.

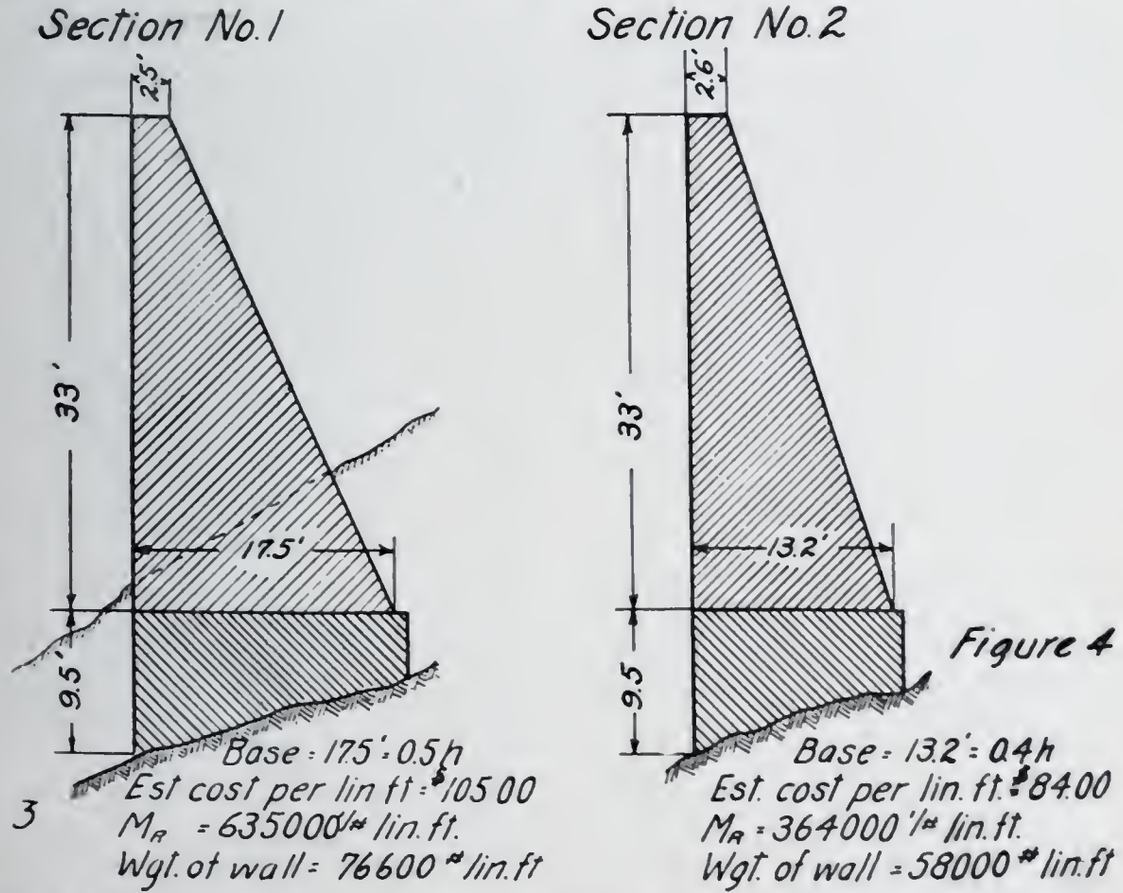


Figure 3. Sketch of proposed Section No. 1, Dilworth Street retaining wall.

Figure 4. Sketch of proposed Section No. 2, Dilworth Street retaining wall.

	co-ef. ϕ	Thrust lbs. lin. ft.	Point of Application	Equivalent fluid pressure	Overturning Moment M_t	Moment of Stability M_s	X=dist. toe to c. g. of resultant	Base Bearing in feet	Comp. at toe lb. per sq. ft. Remarks
P	33°-42″	17100	⅓h	31.5	188,000	447,000	5.85	17.5	C= 8800 lb.
P	45°	10200	⅓h	18.7	112,000	523,000	6.83	17.5	
Q′		16400	⅔h		361,000	274,000	3.58	10.7	C=14300 lb.
Q		47000	1/6h		258.000	377,000	4.9	14.75	tension in heel
U′		2?000	⅔h		635,000				
U	′	58000	⅓h		635,000				
	STABILITY OF PROPOSED GRAVITY SECTION NO. 1.—FIG. 3.								
P	33°-42″	17100	⅓h	31.5	188,000	176,000	3.04	9.1	*C=12700 lb.
P	45°	10200	⅓h	18.7	112,000	252,000	4.35	13.1	C= 8900 lb.
Q′		16400	⅔h		361,000				
Q		47000	1/6h		258.000				
U′		16500	⅔h		364,000				
U		33000	⅓h		364,000				
	STABILITY OF PROPOSED GRAVITY SECTION NO. 2.—FIG. 4.								

*Note—Tension in heel of wall=2200 lb. per sq. ft.

Table No. 1.

The tabular results show the conditions existing and the comparative factors of safety under different loadings. Under the normal loading *P*, the resultant as designed, passes through the middle third, the compression at the toe being 8800lb., which would be safe.

Under Q^1 the moment of stability of the wall is considerably reduced and assuming that the concrete does not split under the tension the resultant cuts the base of the 33 ft. section 3.58 ft. from the toe so that but 10.7 ft. of the base would be bearing.

The wall designed with base equal to .4 the height has a base of 13.2 ft. As shown in the tabulation the possible development of a thrust, due to a decrease in the angle of repose to 33 deg. 42 min., would throw the back of the wall into tension. Under the force Q^1, due to tipping of the earth wedge, and also under *Q*, due to sliding, which would be more probable in this case, the moment of stability of the wall is very much reduced.

Design of Reinforced Concrete Retaining Wall for Height of 35 ft. The reinforced retaining wall, a section of which is shown in Fig. 5, was designed so that it would have a resisting value under normal thrust P equivalent to that of the plain wall with a base of $.5h$ and that at the same time to be safe under more excessive loads. The wall was, therefore, designed so that the resultant due to the lateral thrust produced by the fill under the assumption ϕ=33 deg. 42 min. would pass through the middle third and the stresses in the structure to be at working value. Under higher loads, such as might be caused by forces Q or Q^1, or pressures developed by freezing or settlement of fill, the stresses allowed were higher, approaching the elastic limit for maximum possible conditions.

The width of base was determined in accordance with the method stated before under design of reinforced concrete retaining walls. The required width of base as computed was 17.2 ft., and the width taken for the design was 17.5 ft., including a six inch toe projection.

Table No. 2 gives the results obtained in the investigation and these results may be compared with those obtained in the investigation of the gravity walls. It will be seen that the wall possesses a greater factor of safety than does the gravity wall with a base of $.4h$ under the same conditions of loading, since the gravity wall of this width base would be in dangerous condition.

Thrust	Co-ef. ϕ	Thrust lb. lin. ft.	Application of thrust	Equivalent fluid p	Overturning Moment Ms	Moment of Stability Ms	X=dis. toe to c. g. of resulatnt	Base Bearing feet	Comp. at toe lb. per sq. ft.
P	33°-42″	17,100	⅓h	31,4	222,000	398,000	5.6	16.8	8,500
P	45°	10.200	⅓h	18.7	133,000	487,000	6.8	17.5	8,100
Q′		16,400	⅔h		393,000	227,000	3.2	9.6	14,800
U′		47,500	⅓h		620,000				
U		26,000	⅔h		620,000				
Q		47,000	1/6h		352,000	268,000	3.8	11.4	12,500

Estimated cost of section .....=$85.00
Contract cost of section .....= 56.00
Actual cost of section .....+ 15%= 77.00

Table No. 2. Stability of Wall.

In comparison to the gravity wall with a base of .5*h* the reinforced wall is fully as safe under normal conditions while under more excessive forces it possesses greater resisting power owing to the type of its construction.

It will also be seen that the estimated cost of the reinforced section is about the same as that estimated for the gravity wall with a base of .4*h* and is considerably less than that estimated for a gravity wall with a base of .5*h*.

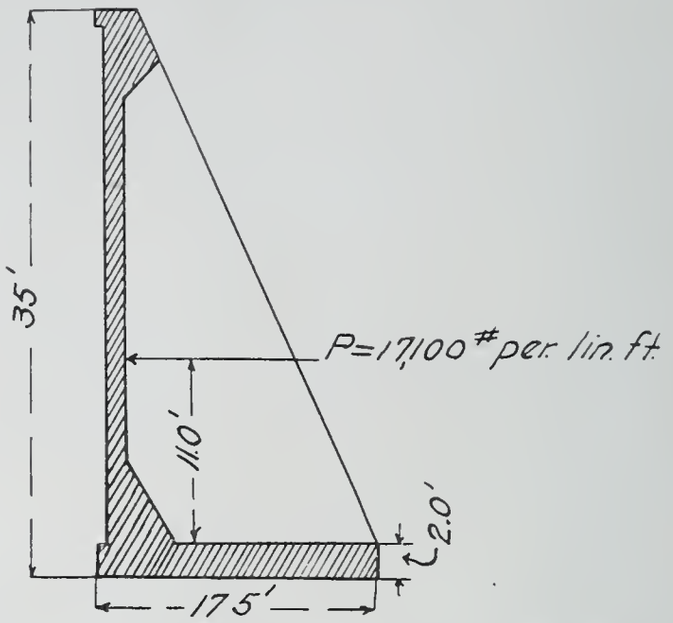


Figure 5. Sketch of adopted design, Dilworth Street retaining wall.

Comparative Designs for Other Depths. Designs and estimates were prepared for the other depths and the results obtained and the estimated costs are given in Table No. 3.

The conclusions drawn from the comparative estimates made for the 30 ft. and 21.5 ft. heights indicate that the reinforced concrete walls would be as economical to construct as a gravity wall with a base .4 the height but that the reinforced concrete type would possess a far greater factor of safety. It was therefore decided to construct the entire wall of reinforced concrete.

The reinforced wall as before stated was designed for three depths, 35, 30 and 21.5 ft. respectively from top of wall to bottom of floor. The wall was also designed so as to rest upon piers extended along the front of the wall and underneath each rib. The data used in the design conforms to that given under design of reinforced concrete retaining walls. In this discussion

ITEM OF WORK	1 Estimated quantity	2 Estimated cost per unit	3 Estimated cost per lin. ft. of wall	4 Price bid contract price per wall	5 Contract price per lin. ft. of wall	6 Actual quantities placed per lin. ft.	7 Actual contract cost per lin. ft.	8 Cost Acct. per unit	9 Cost Acct. per lin. ft.
35 FT. REINFORCED CONCRETE WALL, 37.5 FT. LONG—PER LINEAL FOOT.									
Excavation .....cu. yd.	8.6	$0.80	$ 6.88	$ .50	$ 4.30	9.33	$ 4.67	$0.645	$ 6.02
Reinf. Concrete ....cu. yd.	5.6	8.50	47.60	5.25	29.40	6.38	33.50	6.68	42.62
Plain Concrete .....cu. yd.	0.8	6.00	4.80	5.00	4.00	0.70	3.50	4.00	2.80
Steel Reinf'mt. .....lb.	629	.04	25.16	.02¾	17.29	604	16.60	.0245	14.80
Structural Steel .....lb.	37.8	.02½	.95	.03½	1.32	43.8	1.53	.022	.96
Total per lin. ft.....			$85.39		$56.31		$59.80		$67.20
Estimated cost of gravity wall $b=.5h$ designed for 33° 42′ = $105.00									
Estimated cost of gravity wall $b=.4h$ designed for 45° = 84.00									
30 FT. REINFORCED CONCRETE WALL, 37.0 FT. LONG.									
Excavation .....cu. yd.	4.5	$0.80	$ 3.60	$ .50	$ 2.25	5.70	$ 2.85	$0.533	$ 3.04
Reinf. Concrete ....cu. yd.	4.15	8.50	35.28	5.25	21.79	4.38	23.00	6.88	30.13
Plain Concrete .....cu. yd.	0.24	6.00	1.44	5.00	1.20	0.64	3.20	4.20	2.70
Steel Reinf'mt .....lb.	375	.04	15.00	.02¾	10.31	382	10.50	0.277	10.58
Structural Steel .....lb.	33	.02½	.83	.03½	1.15	38	1.33	0.22	.84
Total per lin. ft.			$56.15		$36.70		$40.88		$47.29
Estimated cost of gravity wall base $=.4h$ = 10.4 ft. = 51.20									
Estimated cost of gravity wall base $=.5h$ = 13.0 ft. = $64.30									
*21.5 FT. REINFORCED CONCRETE WALL, 37.2 FT. LONG.									
Excavation .....cu. yd.	2.31	$0.80	$ 1.85	$ .50	$ 1.15	3.15	$ 1.58	$0.596	$ 1.88
Reinf. Concrete ....cu. yd.	2.44	8.50	20.74	5.25	12.80	2.5	13.12	6.806	16.99
Plain Concrete .....cu. yd.	0.24	6.00	1.44	5.00	1.20	.48	2.40	4.47	2.15
Steel Reinf'mt.....lb.	215	.04	8.60	.02¾	5.92	204	5.61	0.278	5.68
Structural Steel .....lb.	23	.02½	.57	.03½	0.81	26	0.91	0.22	0.57
Total per lin. ft.....			$33.20		$21.88		$23.62		$27.27
Estimated cost of gravity wall base = $.4h$ = 8.6 ft. = $39.40									

*Note: Estimated cost of a reinforced concrete wall of cantilever type, 21 ft. high, designed for ϕ = 33 deg. 42 min. and stress in steel calc. at 8000 lb. per sq. in. under twice the normal thrust was $32.20.

Table No. 3. Dilworth Street Wall—Cost Data.

only the design of the deepest section is given, the design of the other sections being made in a similar manner.

Design of Front Wall. The front wall transmits the lateral thrusts to the ribs and is designed as a slab fixed at the ribs. The connection between the ribs and the front wall, see Fig. 4, Plate 1, was designed so as to fix the wall to the ribs and as placed this assumption is practically correct. The bending moments at the centre of the slab were computed in accordance with the formula $wl^2 \div 15$ and at supports $Me = wl^2 \div 12$. In actual detailing the percentage of steel is varied so as to give convenient spacing to facilitate erection.

Diagram No. 1, Plate No. 1, shows the triangles of pressure applied to the front wall, the loadings marked thereon being in lb. per sq. ft.

The front wall slabs were designed as follows:

The stress in the steel is equal to 10 000 lb. per sq. in. under normal loading from the base to the point b which is 18 ft. below the top of the wall. From this point up the wall was considered to be under a uniform lateral thrust of 565 lb. per sq. ft. with a tension in the steel of 10 000 lb. It will be seen from an inspection of this diagram that under the load Q^1 the steel at the top of the wall will be stressed to about 18 000 lb. while at overturning the steel would be stressed to 27 000 lb. per sq. in. The unit stresses used are low for reinforced concrete work, but in fixing these stresses the character of the construction was taken into account.

In connection with the detailing of this wall it will be noticed at the ribs the rods are placed through holes punched in structural steel angles. This assures the alignment and securing of the rods and at the same time affords a secure manner of tying the front wall to the ribs. As shown on the plan a double line of reinforcement is used in the front wall. Some difficulty was encountered in placing the rods in the back row and it would probably be more economical to design the front wall as a simple slab with bent rods for the negative moment at the points of support.

Design of Rib Reinforcement. The ribs were computed as cantilevers fixed at the base where they are tied into the floor which is held by the superimposed load of earth. Tentative designs were made for panel spacing of 7.5 and 9.0 ft. The nine foot spacing proved to be the more economical.

The rib rods are run down the back of the wall, some of the rods extending into the projection at the heel and some of them being placed under transverse one inch rods which in turn engage the reinforcement in the floor. In this manner the secure anchorage of the rib rods is obtained and the distribution of the stresses between the floor and the rib effected. To insure the bond between the floor and the ribs vertical ties were also added.

The method of designing the reinforcement of the ribs was similar to that employed for designing the front wall. The ribs were investigated in sections five feet apart, the percentage of steel determined and the rods were carried a sufficient distance beyond the point required in order to give secure anchorage, then were bent as shown in order to avoid crushing the concrete.

The stress in the rib reinforcement varies from 10 000 lb. for the normal loading up to 40 000 lb. under the ultimate load and were proportioned to develop the same strength as that of the front wall. Stress diagrams for the different sections and under the different loads were drawn similar in form to those prepared for the front wall.

Design of Floor. Diagram No. 2, Plate 1, illustrates the method used in fixing the unit stresses in the floor reinforcement. The floor reinforcement consists of double reinforcement so as to provide for negative moments at the base of the ribs and so as to carry the resultant pressures.

Under the normal thrust P the resultant cuts nearly at the middle third so that the upward reaction is a triangle, the maximum pressure being twice the average at the toe; this condition is shown graphically in Diagram 2, Plate 1, being indicated by the pressure triangle *gdf*. The downward pressure caused by the weight of superimposed earth is taken as the weight of the wall plus the earth and considered as uniformly distributed, see Diagram 2, Plate 1, area *abcd*. The difference

between the upward and downward pressure gives the resultant pressure which the floor must be designed to carry. For this condition the resultant pressures are shaded in Diagram 2, Plate 1.

As the loading is increased beyond that produced by the normal thrusts a greater width of the floor is subjected to the downward pressure at the same time the intensity of upward resultant at the toe increases. In order to proportion the wall so as to give all parts equal strength under the same conditions the floor was designed to take the stresses caused by a loading of twice the normal, the resultant of which cuts the base at a distance of 2.48 ft. from the toe and causes the upward reaction as shown in the diagram. Under Q the resultant cuts the base 3.11 ft. from the toe.

The floor was designed so as to take the varying loads, the first 7.5 ft. from the heel being designed to carry the weight of the fill under a unit stress in steel of 12 000 lb. The next 4.5 ft., which is not subjected to downward pressure, except under the excessive loads, was designed for a unit stress in steel of 16 000 lb. The front portion of the floor was designed to take the upward resultant caused by the loading $2P$, or twice the normal, the triangle *alh,* Diagram No. 2, Plate 1, showing the loading. The allowable stress under this loading was 24 000 lbs.

All unit stresses in the floor, however, caused by the normal loading do not exceed 12 000 lb. In this manner the floor is proportioned so as to develop the strength of the floor and ribs. Under loading approaching the ultimate the upward resultant of course becomes very great and for this reason the change in section between the front wall and floor is made gradual as shown in the typical sections.

Design of Heel Projection. Under the normal thrust P of 17 100 lb., the weight of the wall being 71 000 lb., the necessary coefficient to prevent sliding would be 0.24. It was assumed that the tangent of the angle of friction would be not less than 0.33. Under the ultimate thrust to be carried by the wall of 47 000 lb., deducting the resistance due to friction of 23 000 lb. leaves a balance to be taken by the heel projection of 24 000 lb. Under the loading of twice the normal, giving a thrust of

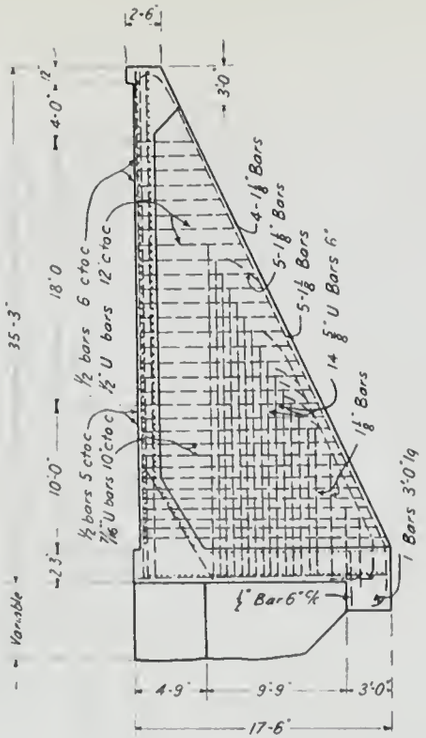
34 000 lb., the thrust to be taken by the heel projection would be 11 000 lb. per lineal foot, the projection was therefore designed as a cantilever to resist this thrust of 11 000 lb. per lineal foot with unit stress in steel of 16 000 lb. Under the ultimate loading the stress in steel would be 35 000 lb. The reason for carrying down this toe projection was that the piers in front of the wall could not be relied upon to prevent sliding without carrying them to considerable depth while the back of the wall being carried into shale excavation afforded an advantageous and economical method of preventing slipping. The design of the heel projection is shown in Fig. 5, Plate 1.

Tie Rods in Ribs. The vertical tie rods tying the ribs to the floor of the wall were proportioned to carry the resultant downward pressure and transmit the same to the ribs that were carried up through the rib and hooked over the horizontal tie rods.

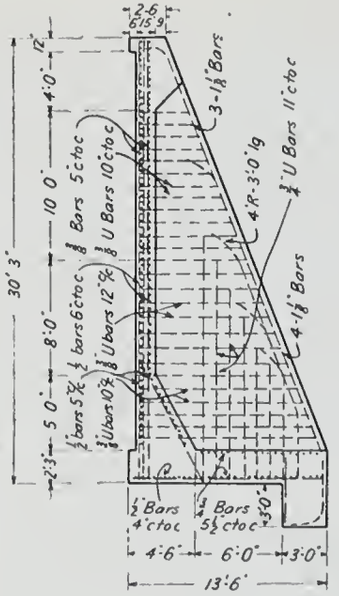
From the theoretical stand point these tie rods are not necessary but it was thought that a much more rigid and permanent construction could be obtained. The unit stress in these rods was fixed at 20 000 lb. per sq. in.

The horizontal tie rods were designed to transmit the lateral thrusts from the front wall to the ribs. The unit stress in these rods was fixed at 20 000 lb. per sq. in., the stress being taken at this value on account of the liability of excessive loads over any portion of the wall. At overturning, considering the thrust causing overturning as applied either at $\frac{1}{3}$ or $\frac{2}{3}$ the height, the stresses in these tie rods is about 40 000 lb. but necessarily varies in different portions of the rib. The horizontal tie rods also insure the distribution of the stresses and make secure the bond between the front wall and the ribs. The horizontal tie rods were made in *U* shape, being passed around the structural angles in the front of the wall and hooked around the rib reinforcement in the back of the wall. It will thus be impossible for the ribs of the front wall to separate without tearing out the longitudinal reinforcement in the front wall.

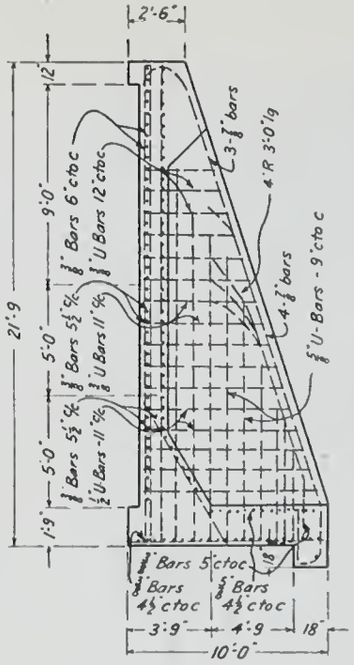
Cost of Dilworth Street Wall. Table No. 3 gives the details of the cost of the three sections of the Dilworth street wall; column 8 gives the cost account per unit as kept by the



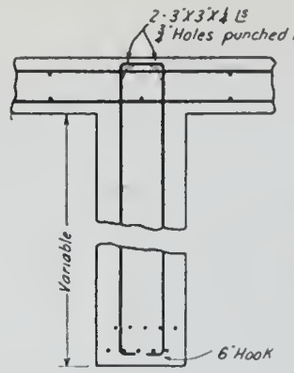
SECTION OF 35FT WALL
FIG 1



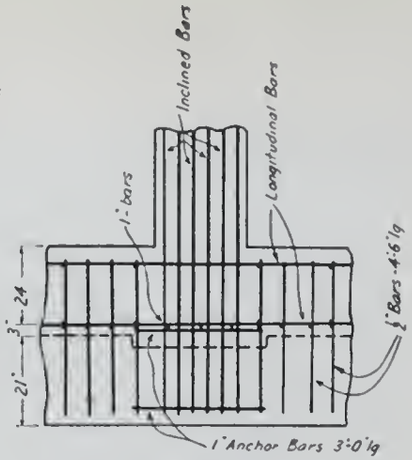
SECTION OF 30FT WALL
FIG 2



SECTION OF 21FT. WALL
FIG 3



DETAIL OF HORIZONTAL
U BARS
FIG 4



DETAILS OF BARS IN BASE
FIG 5

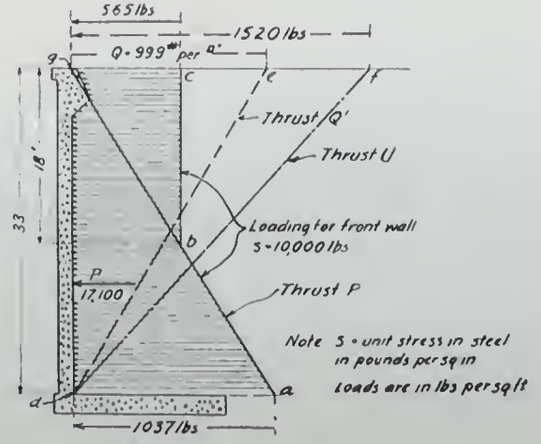


DIAGRAM No.1
Design of Front Wall
Loads & Stresses

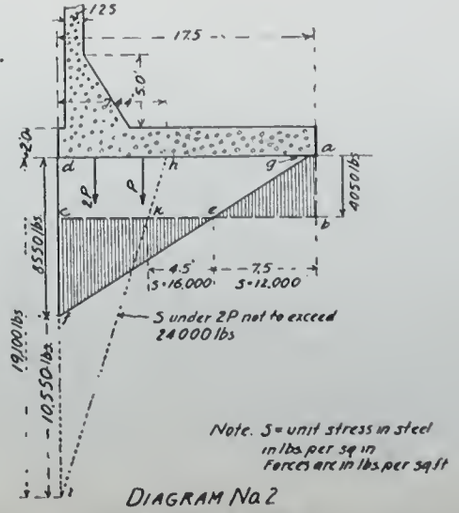


DIAGRAM No.2
Resultant loads on floor

PLATE 1

Plate 1. Details and diagrams of design, Dilworth Street retaining wall.

engineer in charge; the costs are exclusive of general superintendence, of depreciation and interest, and of profit.

Construction. Concrete was mixed in the following proportions:

Plain concrete in piers 1:3:7; reinforced concrete 1:2½:5.

The gravel used was Allegheny River gravel conforming to the requirement that it should be graded from fine to coarse ranging in size from 1½ inch to ¼ inch.

STANTON AVENUE RETAINING WALL

This wall was constructed during 1908 and 1909. The walls were built to replace portions of an old wall which had fallen by overturning. The site of the wall is on Stanton avenue along the hillside bordering the Allegheny Cemetery. The old wall was laid with a facing of rough rubble and was poorly bonded. The stone was sandstone of poor quality, and the old masonry was laid in lime mortar which had almost entirely disintegrated. The back of the wall was stone of assorted sizes and very poorly bonded. Repairs had been made to the old wall at various times and several very heavy buttresses or counterforts had been built. The character of the material is shown in Fig. 3, Plate No. 2. The slope in front of the wall is steep, extending 500 or 600 feet to the valley below. The material is mostly red clay underlaid with shale. The slope in front of the wall had slipped, the surface of the ground showing cracks several feet in depth, these cracks extending down the slope several hundred feet. The old wall seems to have failed on account of the slipping of the material in front of it. The filling behind the wall was found to be a mixture of yellow and red clay which, during dry weather, cracks up and freely admits water. There was no provision for drainage in the old walls, which probably contributed largely to their failure.

It was proposed to replace the portion of the wall that had fallen and with this in view designs were made for reinforced concrete retaining walls of two depths, 20 ft. and 15 ft. respectively. It was proposed, if necessary, to go below this depth, to utilize the stone recovered from the old wall, using such stone as was satisfactory.

After the contract was let it was found impracticable to build the wall without carrying the base to shale. Owing to the fact that the slope in front of the wall continued to slide owing to its angle of inclination and also to the fact that it was necessary to go a depth of from eight to ten feet under a portion of the 20 ft. section, it was decided to change the detail of the reinforced wall in some respects. The base was increased from nine to ten feet and the dimensions of the wall at other sections was also increased. No change was made in the quantity of steel. This section was built upon the rubble base as shown in Fig. 1, Plate 2. The reason for increasing the base to a greater width was to transmit the resultant pressure to the rubble base in a safe manner and also, to a limited extent, to provide for a depth of pressure exceeding 20 ft. The original design of the 15 ft. section, Type *B*, was not changed. See Fig. 2, Plate 2.

The 20 ft. wall, Type *A*, Fig. 1, Plate 2, was originally designed and a portion constructed so that the resultant would pass through the middle third, the angle of repose for the fill being assumed at 45 deg. The wall was, however, designed with the working stresses in the steel at 8000 lb. for a pressure of twice the normal. The moment of resistance of this wall, the weight of fill being taken at 100 lb. per cu. ft., was 89 300 foot pounds per lineal foot.

Table No. 4 shows the stability of the wall under the different conditions. The width of base of this section was nine feet and the height was 20 ft.

The stress in the steel was fixed at this figure, under twice the normal thrust, in order to provide for heavier loading coming upon the upper part of the wall and to develop the full strength of the wall.

An approximate method was used to determine these loads coming upon the upper part of the wall. The angle of repose was assumed at 45 deg. and the wedge of earth behind the wall was assumed to be supported equally by the back of the wall and by a line 45 deg. with the horizontal.

Thrust	Angle of repose	Thrust in lb. per lin. ft.	Point of application	Equivalent fluid pressure	M_t per lin. ft.	M_s-ft. lb. per lin. ft	X-distance from toe to resultant	Base bearing	Remarks
P	45°	3400	$\frac{1}{3}$h	17.2	22 700	66 600	3.3	all	C. at toe = 4050 lb. per sq. ft.
2P	45°	6800	$\frac{1}{3}$h	34.4	45 400	44 900	2.23	6.69	C. at toe = 6400 lb. per sq. ft.
P	33° 42′	5720	$\frac{1}{3}$h	28.6	38 200	51 100	2.32	6.96	C. at toe = 6100 lb. per sq. ft.
Q[1]		5500	$\frac{2}{3}$h		73 500	15 800	0.75	2.25	C. at toe=18 000 lb. per sq. ft.

In this design: γ=100 lb. cu. ft.; base=9 ft.; weight of wall and earth=20 200 lb. per lin. ft.

Table No. 4. Design of Stanton Avenue Retaining Wall, Stability Table.

Costs. The estimated costs and contract prices for the units of work were as follows:

Item of Work.	Estimated Cost.	Contract Price.
Excavation per cu. yd.....	$ 1.00	$ .58
Reinforced concrete per cu. yd.....	10.00	6.73
Plain concrete per cu. yd.....	7.50	4.50
Rubble masonry per cu. yd.....	5.00	2.85
Steel reinforcement per lb.....	.05	.03
Pipe drains, per lineal foot.....	1.00	.80
Fence per lineal foot.....	1.50	1.75

Based on these prices the estimated cost of the 20 foot wall with a nine foot base was $25.50 per lineal foot. The cost of the reinforced concrete and steel alone was $19.30 per lineal foot.

The cost of the 15 foot wall, Type *B*, with seven foot base as designed and built was $16.95 complete per lineal foot, the costs of the concrete and steel being $12.14.

Other prices bid per lineal foot for this wall varied from $16.50 to $28.20 per lineal foot. For the 20 foot wall the other prices bid varied from $26.70 to $39.00 per lineal foot.

Tables Nos. 5 and 6 give the detail estimate of quantities, estimate of cost and contract prices per unit for the 15 foot and 20 foot walls.

Description of Work	Unit	Estimated quantity per lin. ft.	Estimated cost per unit	Estimated cost per lin. ft. of Wall	Contract price per unit	Contract cost per lin. ft. of Wall
Excavation	cu. yd.	6.3	$1.00	$6.30	$ .58	$ 3.65
Reinforced concrete	cu. yd.	2.22	10.00	22.20	6.73	14.94
Plain concrete*...	cu. yd.		7.50		4.50	
Steel Reinforcement	lb.	145.0	0.05	7.25	0.03	4.35
Rubble Masonry* ..	cu. yd.		5.00		2.85	
Drains	lin. ft.	1.0	1.00	1.00	.80	.80
Iron Pipe Fence...	lin. ft.	1.0	1.50	1.50	1.75	1.75
Total per lin, ft.				38.25		25.49
Total per lin. ft. concrete and steel only ..				29.45		19.29

*Used as required.

Table No. 5. Stanton Avenue Reinforced Concrete Retaining Wall, Quantities and Cost Per Unit of Work and Per Lin. Ft. 20 Foot Wall, Type A, 9 Foot Base.

Description of Work	Unit	Estimated quantity per lin. ft.	Estimated cost per unit	Estimated cost per lin. ft. of Wall	Contract price per unit	Contract cost per lin. ft. of Wall
Excavation	cu. yd.	6.3	$ 1.00	$ 6.30	$ .58	$ 3.65
Reinforced concrete	cu. yd.	1.44	10.00	14.40	6.73	9.69
Plain concrete*	cu. yd.		7.50		4.50	
Steel Reinforcement	lb.	81.0	.05	4.05	.03	2.43
Rubble masonry*	cu. yd.		5.00		2.85	
Drains	lin. ft.	1.0	1.00	1.00	.80	.80
Iron pipe fence	lin.ft.	1.0	1.50	1.50	1.75	1.75
Total per lin. ft. (Except extra base) complete				24.85		16.93
Concrete and steel per lin. ft.				18.45		12.12

*Used as required.

Table No. 6. Stanton Avenue Reinforced Concrete Retaining Wall, Quantities and Cost Per Unit of Work and Per Lin. Ft. for 15 Foot Wall, Type B, See Fig. 2, Plate 2.

Design and Cost of 20 ft. Wall with 10 ft. Rubble Base. As before outlined this section, which is shown on Plate No. 2, Fig. 1, was designed for more severe conditions than the original design. The dimensions of the sections of the wall were increased and the base increased from nine to ten feet.

Table No. 7 is a tabulation showing the stability of the wall under the different assigned forces, and Table No. 8 gives the quantities and the cost per lineal foot.

Thrust	ϕ	Thrust in lbs. lin. ft.	Point of application	P	Overturning moment M_t	Moment of stability M_s	X=distance from toe to resultant	Base bearing
P	45°	3 400	⅓h	17	22 700	86 800	3.89	All
2P	45°	6 800	⅓h	34	45 400	64 100	2.85	8.7
P	33° 42″	5 700	⅓h	28.6	38 200	71 300	3.20	9.6
Q_1		5 500	⅔h		73 500	36 000	1.6	4.8

Table No. 7. Stanton Avenue Reinforced Concrete Retaining Wall. Stability Table for Wall, Type A, 20 Ft. High, 10 Ft. Base, See Fig. 1, Plate 2, Computed to the Bottom of 24 Ft. Section.

Table No. 8 gives the quantities and the cost per lineal foot.

Description of Work	Unit	Estimated quantity per lin. ft.	Esitmated cost per unit.	Estimated cost per lin. ft.	Contract price per unit.	Contract cost per lin. ft.
Excavation	cu. yd.	12.9	$ 1.00	$12.90	$ .58	$ 7.48
Reinforced concrete	cu. yd.	2.32	10.00	23.20	6.73	15.61
Steel reinforcement	lb.	145.0	.05	7.25	.03	4.35
Drains	lin. ft.	1.0	1.00	1.00	.80	.80
Fence	lin. ft.	1.00	1.50	1.50	1.75	1.75
Rubble masonry	cu. yd.	4.10	5.00	20.50	2.85	11.68
Total including 10 ft. rubble base				66.35		41.67
Total exclusive of rubble base				45.85		29.99
Concrete and steel only				30.45		19.96

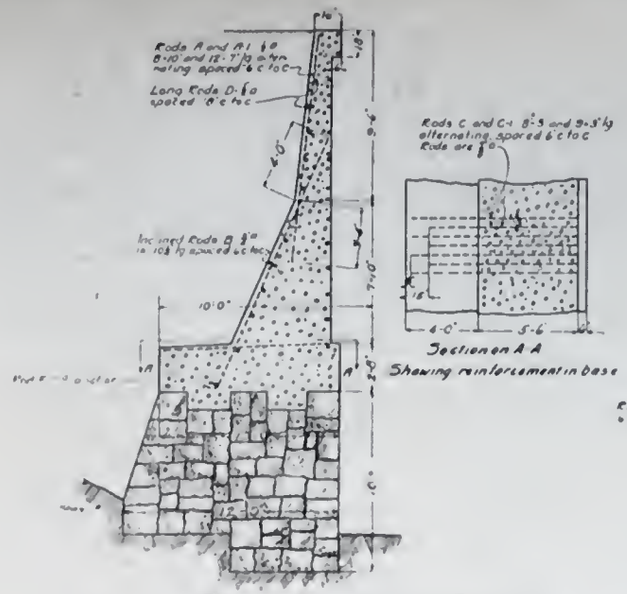
Table No. 8. Stanton Avenue Reinforced Concrete Retaining Wall, Quantities and Cost Per Unit of Work and Per Lin. Ft. or Wall—20′ Section with 10′ Base. See Figs 1 and 3, Plate 2.

A slip of the trench occurred during the progress of the excavation for one of the 20 ft. sections of the wall. The sheeting was not very securely braced in front of the wall and the stringers were anchored across the street to posts driven in the ground, iron rods being passed from the stringers to the posts. The sheeting was not carried deep enough and the fill slipped underneath the same and caused the trench to cave in.

The entire section, composed of the 20 ft. section of reinforced concrete and a rubble base 10 ft. in depth was designed so that the resultant pressure at the bottom of the rubble base cuts the base at the middle third with $\phi = 45$ deg.

SYLVAN AVENUE WALL

The Sylvan Avenue wall was constructed of rubble concrete masonry and was built in connection with the paving of Sylvan Avenue. It was built to replace an old masonry wall that had failed by sliding and settlement. The old wall had settled from three to four feet and had moved out of line several feet down the hill. The old wall had a height of about eighteen feet. The masonry in its face was fair but the back of the wall was very poorly constructed. The surface of the ground in front of the wall slopes sharply down the hill, dropping several hundred feet. There had been an old fill at this point, which the wall was built to retain. After the wall began



TYPICAL SECTION - 20-FT WALL
FIG. NO 1

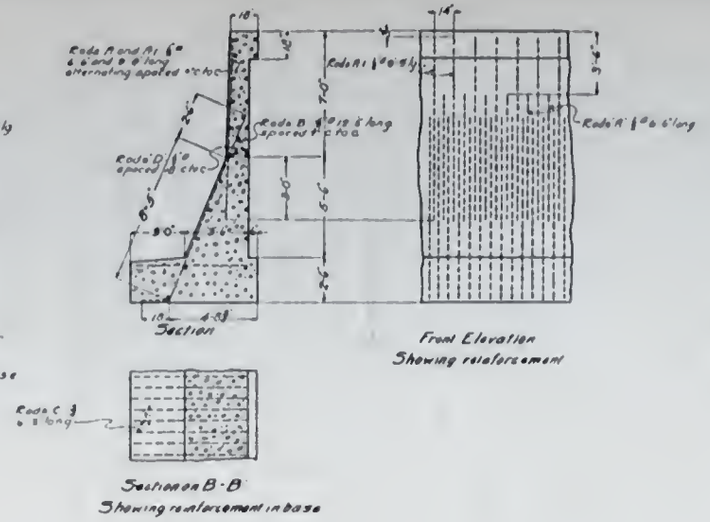
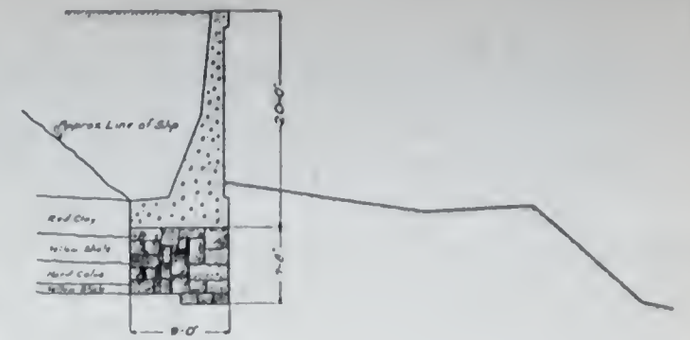


FIG. NO 2
TYPICAL SECTION - 15-FT. WALL
STANTON AVENUE REINFORCED CONCRETE WALL



CROSS SECTION
FIG. No 3

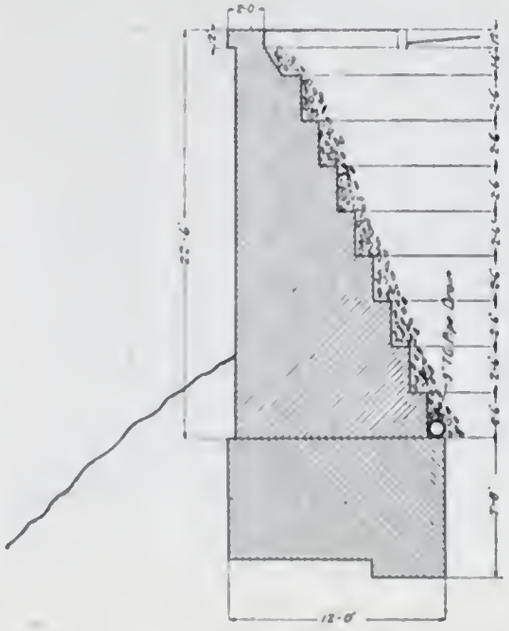


FIG. No. 4

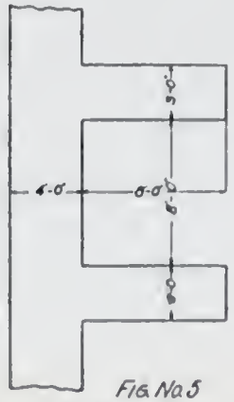


FIG. No 5
Plan of Piers

SYLVAN AVENUE RUBBLE CONCRETE WALL

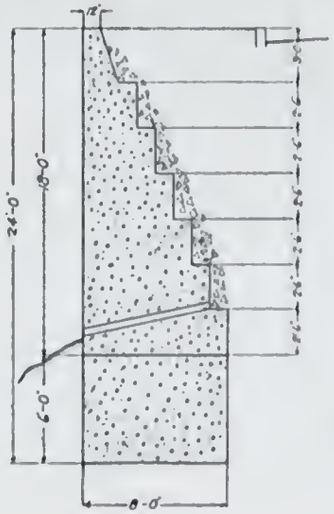


FIG. No. 7
TYPICAL SECTION
ALLEGHENY AVE PLAIN CONCRETE WALL

PLATE 2

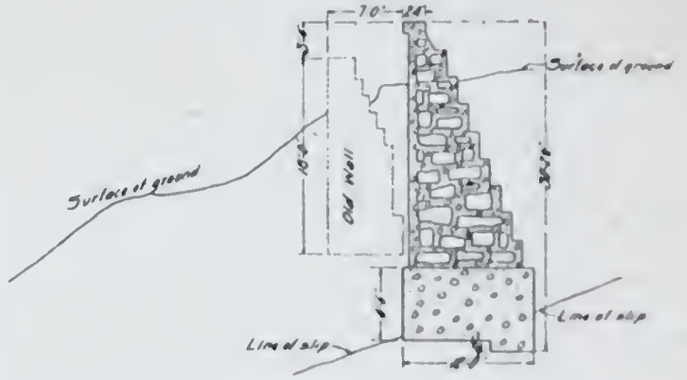


FIG. No. 6
SYLVAN AVENUE WALL
Showing displacement of old wall

Plate 2. Details of the Stanton Avenue, Sylvan Avenue, and Allegheny Avenue retaining walls.

to slip, earth was thrown in front of the wall, which, by adding weight to the slope, did not tend to mend matters. As a consequence of the displacement of this wall, the sewer and water lines occasionally broke and, as the street was to be paved with asphalt, it was decided to remove the old wall and build a new structure.

Test pits were dug on the cross-section and the character of the material was found to be an old fill composed of red and yellow clay which, at a depth of 25 ft. to 30 ft., seemed to indicate the presence of a considerable quantity of water.

The wall is built across an old ravine and rock is found at varying depths, near the surface at the end, and at a depth of about 30 feet in the center. The length of the wall built was about 230 feet.

Comparative designs were made before adopting the final design of a gravity wall of rubble concrete masonry. These comparative designs were based upon a depth of 20 ft., ϕ being taken at 37 deg. 30 min. and, for the reinforced sections, steel was taken at 8000 lb. under the normal loading produced. These walls, with the exception of the gravity wall, were designed so that the resultant would cut the middle third. The estimates were based on reinforced concrete at $10.00 per cu. yd., steel at 5¢ per lb. and excavation at $1.00 per cu. yd. The estimated cost per lineal foot of the cantilever, reinforced concrete wall was $28.00. The estimated cost per lineal foot of the reinforced concrete wall with ribs was $27.50. The cost of the gravity wall with a base of 11 ft. and the same height, the resultant cutting the middle third, was $33.00 per lin. ft., the cost being based on unit cost of concrete of $7.00 per cu. yd., excavation being the same.

A detailed design was then prepared for a cantilever wall with a base of 14 ft. and a depth of 22 ft. under the same assumptions as to loading and stress. Its estimated cost was $39.00 per lin. ft., concrete being taken at $10.00 per cu. yd., steel at 5¢ per lb. and excavation at $10.00 per lineal foot.

It was finally decided that, on account of the fact that much of the material in the old wall could be used in a new structure, to construct the wall of rubble concrete masonry.

This wall was designed under the assumption that $\phi = 33$ deg. 42 min. and γ 120 lb., the equivalent fluid pressure being 34 lb. per cu. ft. In calculating the effective depth of the fill to be resisted, the information gained from the excavation of test pits was used and below the point where the material was firm no allowance was made for lateral pressure.

A typical section of this wall is shown on Plate No. 2, Figures 4 and 6. The contract prices were as follows:

Excavation for retaining wall.....38¢ per cu. yd.
Plain concrete .....$5.20 per cu. .yd.
Rubble concrete ..... 4.60 per cu. yd.

Under a portion of the wall, piers were built through the firm ground to shale, so that slipping of the wall on the inclined strata of rock might be prevented and, at the same time, saving excavation and concrete. Where these piers were built, a section of plain concrete, five feet in depth, was placed, and longitudinal reinforcement consisting of a double line of one inch bars spaced 12 in. centre to centre was placed. The bonding of the upper section of the wall to the piers was secured by placing steel reinforcement in the piers extending up into the plain concrete base. Plain concrete was mixed in proportion of 1:3:6, and the rubble concrete masonry was built in approximately horizontal courses. The stones were bedded in concrete of moderately dry consistency and the joints between the stones were grouted with wet sloppy concrete. The distance between stones and the exterior face of the wall was specified not to be less than six inches.

A typical cross-section of the work is shown in Fig. 6, Plate 2, which shows the line of rupture of the slip that caused the failure of the old wall. This figure also shows the position of the original wall and gives a good idea of the extent of its displacement. Although the wall had moved and settled considerably, as shown in this illustration, the wall itself was intact and but very little distorted. The wall, however, had slid off of its base in some places. This figure also illustrates one of the greatest difficulties in constructing retaining walls in

this vicinity, on hillside locations, which very often necessitates carrying the base a considerable depth to firm ground.

MICHIGAN STREET RETAINING WALL

This wall is a heavy reinforced concrete wall of the cantilever type designed for the surcharge of a new fill placed on a steep slope. The wall was built in connection with the grading, paving and curbing of Michigan Street and was built to protect a roadway in McKinley Park. The wall consists of an arched central portion of reinforced concrete with plain concrete abutments or wing walls at the end. From the back of the wall the embankment slopes up to the street line, the angle of the slope varying with the distance of the wall from the street line.

On account of the location of the wall an attempt at ornamentation was made.

The wall was designed for a normal pressure of twice that developed under the assumption that ϕ would equal 37 deg. 30 min. which approximately equals the angle of inclination of the original surface of the ground. The depth of surcharge was about $5\frac{1}{2}$ feet. The stability and internal resistance of the wall was also investigated under the thrust developed by the forces Q and Q^1. The weight of the wall and the superimposed earth was 25 000 lb., its moment of resistance was 231 000 ft. lb. per lin. ft. The steel was computed for stress in steel of 8000 lb.

In designing the wall the base was spread, the toe being extended five feet on the front of the wall. This extended base was desirable on account of the steep slope of the existing surface and the fact that a mixed clay and earth fill was to be placed. The estimated cost of the wall per lin. ft. was $46.00 and the contract cost per lin. ft. was $42.00.

A comparative design was made for a gravity wall. A gravity wall with a base of 10 ft. and a height of 22 ft. was estimated to cost about $32.00. Under the thrust developed by the normal loading P, one-half of that applied to the reinforced wall, the back of the wall would be in tension since the resultant cut the base 2.9 ft. from the toe. A gravity wall

with a 12 ft. base and 22 ft. high was estimated to cost $37.00, the resultant cutting the middle third.

On account of the conditions it was thought advisable to build the reinforced wall since the cost was but very little greater and it possessed a much greater factor of safety.

Section. The section of the wall is shown in Fig. 6. The vertical rods in the back of the wall, $\frac{7}{8}$ in. rods spaced $4\frac{1}{4}$ in., were extended from the top of the wall to the base. The inclined rods, $\frac{7}{8}$ in. rods spaced $4\frac{1}{2}$ in. center to center, were tied to the vertical rods and also to the transverse rods in the heel, which were $\frac{3}{4}$ in. rods spaced six inches center to center. The end of the inclined rods was hooked over the longitudinal rods in the base. The rods in the extended toe were $\frac{7}{8}$ in. rods spaced four inches center to center. A toe projection was provided, but was not necessary in construction owing to the fact that the base of the wall was in shale. The shape of the wall, also, is such that arching action of the reinforced section against the heavy cencrete wing walls is provided, and provides a very great factor of safety against overturning.

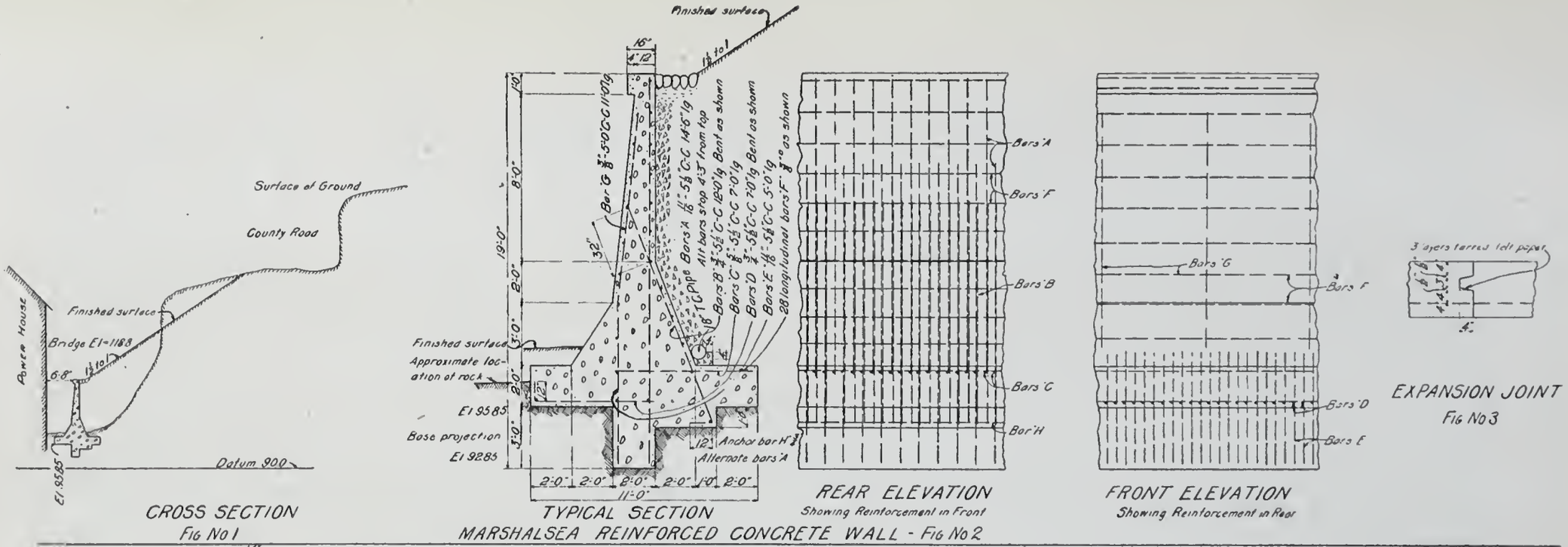
Descript'n of work	Unit	Estimated quantities per lin. ft.	Estimated cost per unit	Estimated cost per lin. ft. of Wall	Contract price per unit	Contract cost per lin. ft. of Wall
Concrete	cu. yd.	3.3	$8.00	$26.40	$8.00	$26.40
Steel reinforcement	lb.	405.0	.05	20.25	.04	16.20
Total per lin. ft.				$46.65		$40.60

Table No. 9. Michigan Street Retaining Wall. Unit Costs and Estimated and Contract Prices. For section see Fig. 6.

Construction. The proportion of concrete in this wall was 1:3:6.

WASHINGTON AVENUE RETAINING WALL

This wall was constructed in 1908 on Washington Avenue, South Side, in connection with the grading, paving and curbing of the street of that name. The street is located near the south end of the traction tunnel. The wall erected is a reinforced concrete retaining wall, cantilever type, 500 ft. long, at each end of which a length of gravity wall of less depth was built, the total length of the gravity walls being 375 ft. The



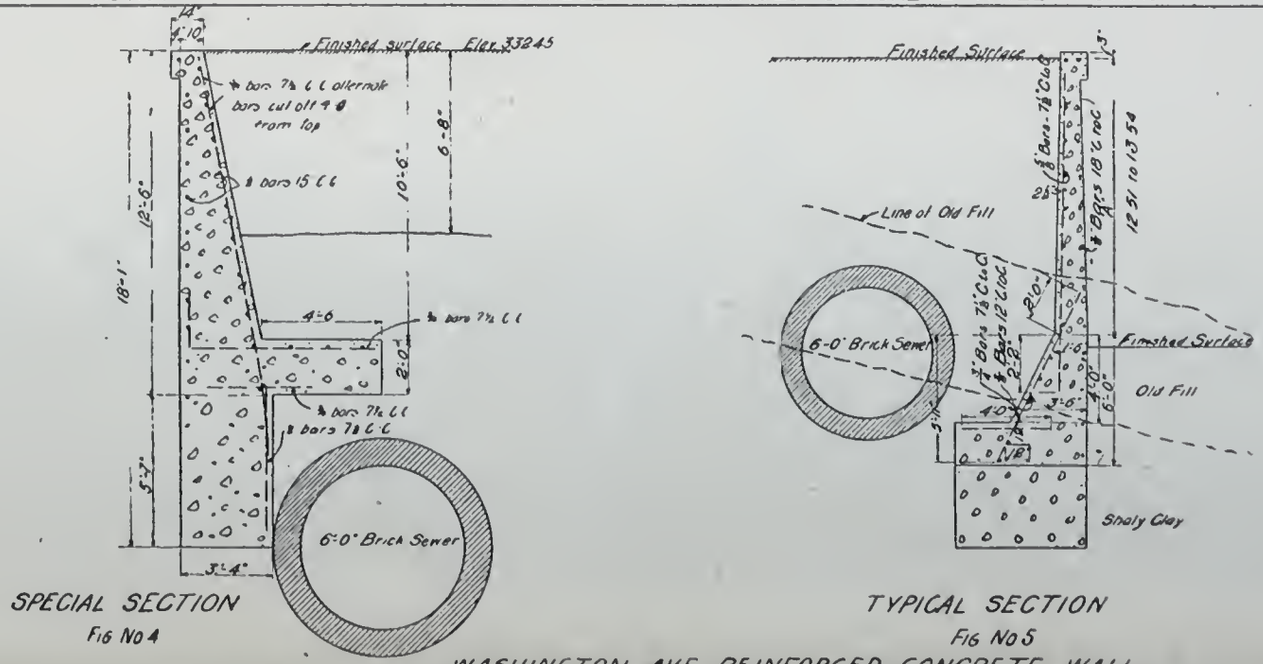


PLATE 3

Plate 3. Details of the Washington Avenue and Marshalsea retaining walls.

construction of this wall was rendered difficult by the fact that a six foot brick sewer had been built near the street line so that the space available for the base of the wall was restricted. In preparing the contract plans, it was anticipated that the width of base would not exceed four feet.

The Castle Shannon railroad, since electrified, runs along the front of the wall a few feet from its face. The distance from the top of wall to top of rail is about 13 ft. and this may be taken as the effective height of the wall. The new fill behind the wall was from seven to nine feet.

The wall was designed for a base of four feet and a depth of 19 ft. from top of wall to bottom of the reinforced wall. It was anticipated that where desired plain concrete would be placed under the base of the reinforced wall.

The concrete was 1:3:6 mix and the wall was built in sections varying from 90 to 60 ft. Plate No. 3, Fig. 5, shows the detail of a section of this wall and also, see Fig. 4, shows a typical detail of a special section, which was necessitated on account of the lack of clearance between the side of the sewer and the street line.

The wall was designed for a depth of fill of from seven to nine feet and the angle of repose assumed for the fill was 45 deg. It was assumed that the excavation through the old fill would exert little if any pressure on the wall. The normal thrust developed, with $\phi = 45$ deg. and $\gamma = 100$ lb. per cu. ft., $= 700$ lb. per lin· ft. of wall. The weight of the wall and the superimposed earth was 9400 lb. per lin. ft. The overturning moment calculated to the base of the reinforced section for $h =$ 19 ft., is $M_t = 9100$ ft. lb. per lin. ft. The moment of resistance of the wall about the toe is $M_r = 18\,200$ lb. per lin. ft. Under this thrust, the resultant cuts the base about one foot from the toe, the base bearing under the thrust being three feet.

While this was considered safe for the character of the fill to be placed, which was to be a mixture of shale and clay, it was thought desirable to carry the base deep, so as to provide an additional factor of safety for overturning. For this reason the depth of the wall was carried six feet below the top of the rail. The steel reinforcement was computed so that the

stress on the steel, under the normal thrust developed, by the earth, with $\phi = 33$ deg. 42 min. would not exceed 8000 lb. per sq. in.

Table No. 10 gives the quantities, estimated cost and contract cost per lineal foot of wall.

Description of Work	Unit	Estimated quantity per lin ft.	Est. cots per unit.	Estimated cost per lin. ft. of wall	Contract cost per unit	Contract cost pe r lin. ft. of wall
Steel reinforcement....	lb.	65	$ .05	$ 3.25	$ .0225	$1.40
Excavation.....	cu. yd.	2.0	1.50	3.00	.50	1.00
Concrete, reinforced...	cu. yd.	1.21	9.00	10.90	6.75	8.20
Plain Concrete.....	cu. yd.					
Fence.....	lin. ft.	1.0	1.50	1.50	1.35	1.35
Total per lin. ft.....				$18.64		$12.95

Table No. 10. Washington Avenue Retaining Wall—Unit Costs and Cost Per Lin. Ft. of Wall. Engineers Estimate and Contract Prices. For Section see Fig. 4, Plate 3.

When the trench was opened up it was found that the line of the sewer was irregular and that, for a considerable portion of the length of the wall, a width of base of from five to six feet was available. The base of the wall was therefore made the full width of the trench and horizontal steel reinforcement was placed in this extended heel, the original design only contemplating a six inch offset two feet from the base.

The distance from the bottom of the reinforced concrete section to the surface of the shale varied from nothing to four feet. With the exception of the first section of 90 ft. the wall was carried to shale, plain concrete being placed under the base of the reinforced section. In order to utilize this depth of reinforced concrete, vertical reinforcement was placed in the back, being hooked over the horizontal rods of the heel.

With a base five to six feet in width the wall has a much greater moment of resistance, the moment of resistance of the wall being increased from about 18 000 to about 41 000 ft. lb. per lin. ft.

Section. The section of the wall consists of a thin section 14 in. wide at the top and 18 in. at the bottom and from 12.5

to 13.5 ft. in depth. This portion is reinforced with $\frac{5}{8}$ in. rods, spaced $7\frac{1}{2}$ in. center to center. The next section is four feet in depth and its thickness is 18 in. at the top and $3\frac{1}{2}$ ft. at the bottom, and is reinforced with $\frac{3}{4}$ in. rods spaced $7\frac{1}{2}$ in. center to center. The transverse rods in the base, which was two feet in thickness, are $\frac{3}{4}$ in. rods spaced $7\frac{1}{2}$ in. center to center. The rods in the upper portion of the wall were cut off alternately four feet from the top.

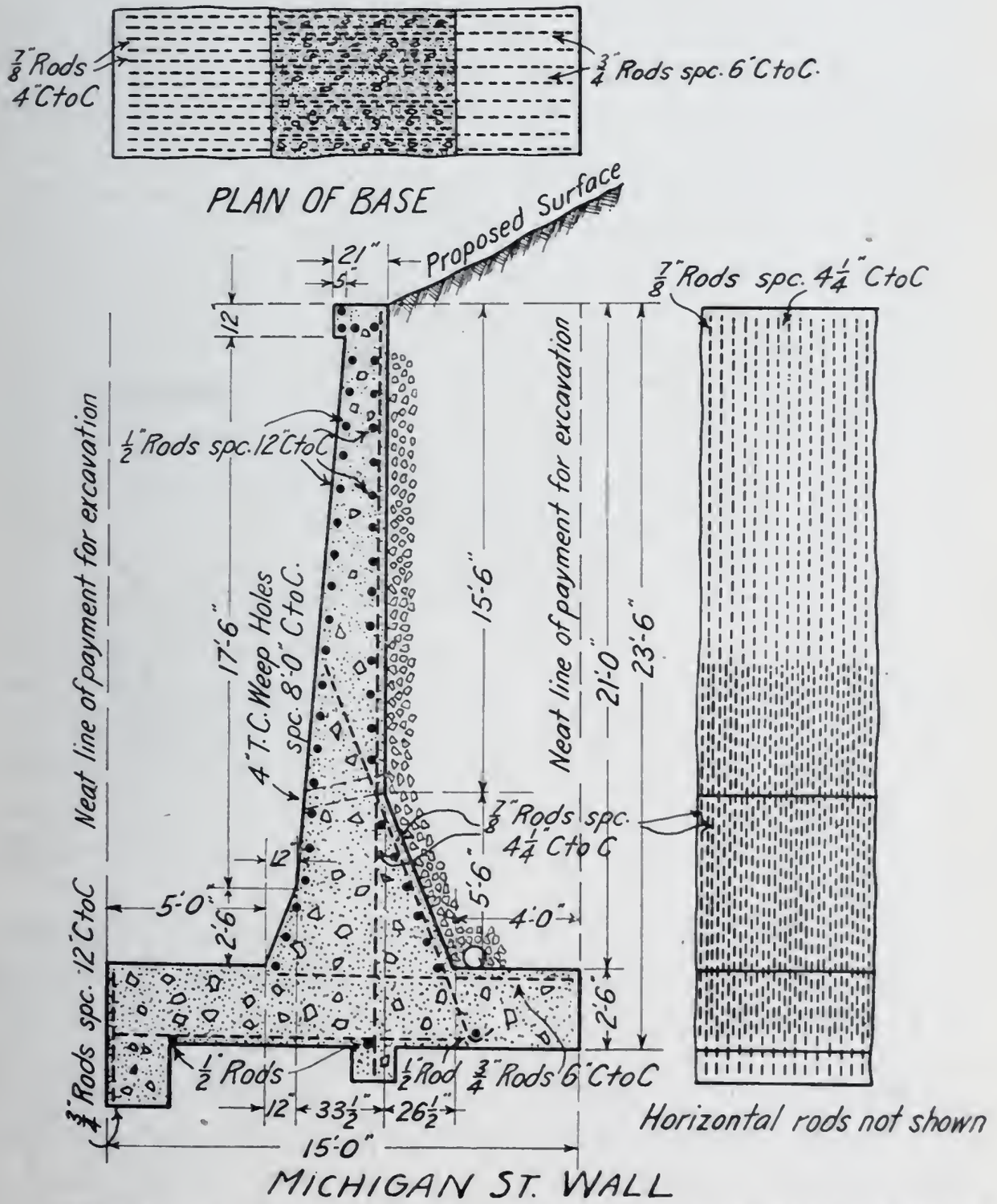


Figure 6. Michigan Street wall, typical section of wall.

Expansion and Contraction. In the first section of the wall, 90 ft. in length, the longitudinal reinforcement, placed so as to provide for temperature stresses and to aid in distributing the stresses, consisted of nine ½ in. rods spaced about 19 in. apart, the percentages of steel in the upper portion being 0.092 percent. The base of the first section was on hard clay. No cracking of the wall resulted. The next section, however, was carried to rock and this 90 ft. section cracked into three parts of approximately 30 ft. in length. The percentage of reinforcement was increased, sixteen ½ in. rods being placed in the upper 13 ft. of the wall, the percentage of the steel then being 0.165 percent. This quantity of the steel seemed to be effective in preventing cracks.

On Plate No. 3, Fig. 4 is shown the detail of a special section, 60 ft. in length, the construction of which was necessitated by the lack of clearance between the side of the sewer and the street line, the space available being only 3.35 ft. A reinforced concrete platform was placed over the sewer, as shown on the plan, to prevent the wall from overturning. Most of the weight of the wall is carried directly on the front wall. The adaptibility and economy of the reinforced type of wall are well illustrated by this design.

MARSHALSEA RETAINING WALL

This wall was built at the City Poor Farm, Marshalsea, to protect the new power house from a sliding bank of earth. The slope had been cut back to admit of the construction of the power house and the bank was slipping. The county road is at the top of the slope and about fifty feet from the power house, the difference in elevation in this distance being about forty feet.

It was desired to provide an open space between the side of the building and the wall. It was also considered hazardous and would undoubtedly result in considerable cost to cut back very far into the slope. A study was made of the comparative cost of sloping the earth and moving the county road back, and of building a retaining wall. The cost of the retaining wall was found to be less than the other project.

The wall constructed, about 100 ft. in length, is a reinforced concrete wall of the cantilever type with an extended toe and a projection of the base into the rock upon which the wall was built. The wall was designed for heavy conditions, the slope already being in motion and consisting of clay on rock. This wall was erected in 1909. The wall designed is safe under the thrust developed by the formula $h = \frac{1}{2} h^2 \cos \phi$, with $\phi =$ to 33 deg. 42 min. The stresses caused by other loadings, such as Q^1 and Q, were also investigated and the stress in the steel under these loadings do not exceed 16 000 to 20 000 pounds.

The section and details of this wall are shown on Plate No. 3, Figs. 1 to 3 inclusive. Its construction necessitated cutting back into the bank but seven feet and the wall as built possesses a large factor of safety, the total width of base being 11 ft. The moment of resistance of the wall is 97 500 ft. lb. per lin. ft. The stresses in the steel for the normal loading is 8000 lb., except the upper portion of the wall, where the stress is somewhat lower, so as to provide for excessive loads coming on this portion of the wall, as might result from sliding of the earth of the steep bank.

Section. The arrangement of the reinforcement in this wall is similar to that of the Michigan Street wall. The reinforcement of the vertical base projection is provided by extending the main vertical reinforcement to the bottom of the projection.

Table No. 11 gives the estimated and contract cost of this wall per lin. ft.

Item of work	Unit	Quantity per lin. ft. of wall	Est. cost per unit	Est. cost per lin. ft. of wall	Contract price per Contract	price per unit lin. ft.
Excavation	cu. yd.	3.5	$1.50	$ 5.25	$0.35	$1.22
Reinforced concrete	cu. yd.	2.27	8.50	19.30	7.30	16.57
Steel reinforcement	lb.	185.0	.04	7.40	.016	2.96
Plain Concrete	cu. yd.				6.00	
Total per lin. ft. of wall				$31.95		$20.75

Table No. 11. Retaining Wall at Marshalsea. Estimated Cost and Contract Price Per Unit of Work and Per Lin. Ft. of Wall. For Section see Fig. 2, Plate 3.

The concrete was mixed in the proportion of 1:2½:5, the size of the gravel being spcified not to exceed 1½ in. or less than ¼ in. The surface of the wall was finished by rubbing with small molded blocks of cement mortar, water being applied at the same time. The finished surface presents a very satisfactory and uniform appearance.

ALLEGHENY AVENUE RETAINING WALL

This wall, a section of which is shown on Plate 2, Figure 7, is a gravity wall of concrete and is typical of the practices of this Department for such construction and the wall was designed to resist a new fill of about eight feet, the footing of the wall to be carried to such depth below this point as might be required. The unit weight of the new fill was assumed at 110 lb. per cu. ft. The resultant of the pressures cuts the middle third under the assumption that the equivalent fluid pressure would be about 23 lb. per cu. ft., which corresponds to an angle of repose for the material of about 42 deg. The contract price for concrete in this wall was $5.75 per cu. yd., and at this price the wall as shown in the figure with a six foot depth of footing cost $28.75 per lineal foot, for concrete alone. Provision for drainage in walls of this type is made by placing a course of broken stone 12 inches in thickness from the top of the wall to firm ground, the drainage discharging through terra cotta pipe placed in the wall. The proportion of concrete used is 1:3:6.

These designs were made under the supervision of Mr. N. S. Sprague, Mem. A. S. C. E., the Superintendent of the Bureau of Construction, to whom the writer is indebted for assistance in preparing the designs and the writer further wishes to acknowledge the assistance of Mr. J. D. Stevenson of this Bureau in preparing this paper.

DISCUSSION

Mr. C. F. W. Rys: In connection with this valuable paper, it might be of interest to say a few words about the qualities and grades of steel that are or ought to be used for concrete reinforcement bars. It has been, and still is, in many cases very difficult, if not impossible, for the manufacturers of such bars to meet certain specifications which have been submitted

to them by different engineers. In many cases the properties specified do not correspond with each other. . For instance, you find that they will call for an elastic limit as high as 50,000 and 55,000 lbs. per sq. in., with a specified elongation that cannot be met in a steel of that high elastic limit. Or in other cases bending tests are specified that cannot possibly be made on a bar of such high elastic limit. For such various reasons, a very thorough and complete investigation was made and the results of thousands of tests on different plain bars, deformed bars and twisted bars, were carefully compiled and analyzed. Based on these tests results a specification was drafted which was adopted in March, 1910, by the Association of American Steel Manufacturers. This specification represents a material for concrete reinforcement bars which not only can be manufactured on a practicable commercial basis, but which also should give very satisfactory results when applied for concrete work.

This specification, given below, has been divided into three classes of material, i. e., plain bars, deformed bars and cold twisted bars. The plain bars and deformed bars have again been divided into two grades, i. e., structural steel grade and hard grade. For cold twisted bars, of course, only one grade of material is used.

STANDARD SPECIFICATIONS FOR CONCRETE REINFORCEMENT BARS

Adopted March, 1910, by The Association of American Steel Manufacturers.

MANUFACTURE

1. Steel may be made by either the open-hearth or Bessemer process. Bars shall be rolled from billets.

CHEMICAL AND PHYSICAL

2. The chemical and physical properties shall conform to the following limits:

CHEMICAL DETERMINATIONS

3. In order to determine if the material conforms to the chemical limitations prescribed in paragraph 2 herein, analysis shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt or blow of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector.

PROPERTIES CONSIDERED	STRUCTURAL STEEL GRADE		HARD GRADE		COLD-TWISTED BARS
	Plain Bars	Deformed Bars	Plain Bars	Deformed Bars	
Phosphorus, maximum,					
Bessemer	.10	.10	.10	.10	.10
open-hearth	.06	.06	.06	.06	.06
Ultimate tensile strength, pounds per sq. in.	55/70,000	55/70,000	80,000 min.	80,000 min.	Recorded only
Yield point, minimum, pounds per sq. in.	33,000	33,000	50,000	50,000	55,000
Elongation, per cent in 8″, minimum	$\frac{1,400,000}{\text{T. S.}}$	$\frac{1,250,000}{\text{T. S.}}$	$\frac{1,200,000}{\text{T. S.}}$	$\frac{1,000,000}{\text{T. S.}}$	5%
Cold bend without fracture:					
Bars under ¾″ in diameter or thickness	180°d.=1 t.	180°d.=1 t.	180°d.=3 t.	180°d.=4 t.	180°d.=2 t.
Bars ¾″ in diameter or thickness and over	180°d.=1 t.	180°d.=2 t.	90°d.=3 t.	90°d.=4 t.	180°d.=3 t.

The hard grade will be used only when specified.

. .

YIELD POINT

4. For the purposes of these specifications, the yield point shall be determined by careful observation of the drop of the beam of the testing machine, or by other equally accurate method.

FORM OF SPECIMENS

5. (a) Tensile and bending test specimens may be cut from the bars as rolled, but tensile and bending test specimens of deformed bars may be planed or turned for a length of at least 9 inches if deemed necessary by the manufacturer in order to obtain uniform cross-section.

(b) Tensile and bending test specimens of cold-twisted bars shall be cut from the bars after twisting, and shall be tested in full size without further treatment, unless otherwise specified as in (c), in which case the conditions therein stipulated shall govern.

(c) If it is desired that the testing and acceptance for cold-twisted bars be made upon the hot rolled bars before being twisted, the hot rolled bars shall meet the requirements of the structural steel grade for plain bars shown in this specification.

NUMBER OF TESTS . .

6. At least one tensile and one bending test shall be made from each melt of open-hearth steel rolled, and from each blow or lot of ten tons of Bessemer steel rolled. In case bars differing $\frac{3}{8}$ inch and more in diameter or thickness are rolled from one melt or blow, a test shall be made from the thickest and thinnest material rolled. Should either of these test specimens develop flaws, or should the tensile test specimen break outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor. In case a tensile test specimen does not meet the specifications, an additional test may be made.

(d) The bending test may be made by pressure or by light blows.

MODIFICATIONS IN ELONGATION FOR THIN AND THICK MATERIAL

7. For bars less than $\frac{7}{16}$ inch and more than $\frac{3}{4}$ inch nominal diameter or thickness, the following modifications shall be made in the requirements for elongation:

(e) For each increase of $\frac{1}{8}$ inch in diameter or thickness above $\frac{3}{4}$ inch, a deduction of 1 shall be made from the specified percentage of elongation.

(f) For each decrease of $\frac{1}{16}$ inch in diameter or thickness below $\frac{7}{16}$ inch, a deduction of 1 shall be made from the specified percentage of elongation.

(g) The above modifications in elongation shall not apply to cold-twisted bars.

NUMBER OF TWISTS

8. Cold-twisted bars shall be twisted cold with one complete twist in a length equal to not more than 12 times the thickness of the bar.

FINISH

9. Material must be free from injurious seams, flaws or cracks, and have a workmanlike finish.

VARIATION IN WEIGHT

10. Bars for reinforcement are subject to rejection if the actual weight of any lot varies more than 5% over or under the theoretical weight of that lot.

I would like to call attention to a few paragraphs in these specifications which are of special interest:

Paragraph 1. Manufacture—It will be noted that the specification calls for bars to be rolled from billets, and this specification, therefore, does not include rerolled material.

In looking over the table giving the properties of these bars, a distinct difference will be noted in the elongations and cold bends specified for plain bars and deformed bars and this point naturally would be raised by concrete people who use deformed bars. The explanation for these differences is the fact that you cannot expect the same amount of elongation or the same bending test results on a deformed bar that you will get on plain bars of the same grade of material. Difficulty has been experienced with bending tests especially on deformed bars that have transverse deformations. The peculiarities of the manufacture of deformed bars also have certain effects. For instance, the necessity of finishing such bars at a very high temperature for the reason that the deformations have to be formed in the last pass of the rolling.

Paragraph 5 (a). Form of Specimens—You will note that the test specimens of deformed bars may be machined if deemed necessary. There is a very good reason for this, because it has been found that you cannot actually determine the cross section of certain deformed bars although the designers of such bars will claim that they have a uniform cross section. It is not possible in such cases to determine absolutely what cross section you can figure on safely in making your tests without machining such bars. Another reason for this is the impossi-

bility of making certain specified bending tests on bars which have transverse deformations, as the sharp off-sets of these deformations interfere severely with the bending of the bars.

Under 5 (c) you will note that the double testing for cold twisted bars has been eliminated. Many specifications call for tests on the plain square and also for tests on the same bar after twisting. I think the deciding test on a twisted bar is the test on the bar after twisting and not on the plain square. In my opinion, it is not of much importance whether the plain square used for twisting has a minimum yield point of 33,000 lbs. per sq. in. before twisting, and I do not see any reason why material giving a yield point slightly below this minimum should be rejected, as the number of twists applied can be arranged in such a way that the specified yield point for the twisted bar will be met.

In other respects, the specifications are self-explanatory. Chemical determinations, variations in weight, modifications in elongation of thick and thin material, are along the lines of well-known standard specifications.

Mr. Willis Whited: I would ask Mr. Rys whether the steel used for twisted bars is not ordinarily soft steel that would run about 60,000 to 65,000 ultimate.

Mr. C. F. W. Rys: Yes, soft steel used for twisted bars.

Mr. A. R. Archer: From the diagrams apparently 110 pounds is used in computing the weight of the retained earth in all cases, and I am aware that this value is in quite common use among engineers. However, it is undoubtedly a fact that the composition and, therefore, the weight of the soil varies in different localities, and I would like to ask whether any tests have been made in this locality to know what the average weight is. With an admixture of clay and shale it would be expected that the weight would be considerably greater than for a loose sandy or loamy soil.

So far as I observed the photographs thrown upon the screen showed that some of the walls were provided with weep holes and others were not. What is the established practice, if any, in this matter?

In regard to the amount of steel to be used for the prevention of contraction cracks, there is a theoretical relation between the steel required and the thickness of concrete forming the wall at any point established by the ratios of the moduli of elasticity for steel and concrete. From the modulus of elasticity and coefficient of expansion of concrete we can determine the stress which is set up for any given range of temperature if the concrete is prevented from contracting or expanding, and sufficient steel should be used to develop this stress together with the stress due to its own contraction or expansion without exceeding the elastic limit of the metal. So far there is nothing indeterminate about the amount of steel needed, but a difficulty arises from the fact that it is very uncertain how the temperatures will range through the thickness of the wall for given air temperatures, and it is in this respect that the engineer's judgment must be exercised.

THE AUTHOR: Relative to drainage, the walls discussed in this paper are all provided with efficient drainage, consisting of a course of broken stone 12 in. in thickness, which extends from near the surface of the ground to or below the footing, as required. Cross drains or weep holes of terra cotta pipe, usually four inch, and spaced from eight to ten feet, are placed transversely in the wall, discharging upon the surface of the ground in front of the wall. In most cases the broken stone backing goes below these drains and in which case puddle is placed just below the level of the weep holes, and the water which gets into the broken stone below the level of the weep holes is carried off by longitudinal drains of double strength terra cotta pipe, varied in size to suit the conditions. This tile drain is laid with open joints and outlets are provided, which in all cases are made as permanent as possible. Sometimes the longitudinal drains are discharged into sewers and in other cases small structures are built on the hillside. We have always thought it better to spend enough money to provide sufficient drainage as that is one of the most important items in all walls.

I do not believe I have anything to add about the provision of reinforcement for the prevention of cracking due to tempera-

ture stresses. It is simply a matter of judgment and theoretical considerations require entirely too much steel, more steel than is known in practice to be necessary. The theoretical consideration of this subject is complicated by the fact that provision must be made for shrinking stresses which occur during the setting of the cement. It is known from practice that the thickness of the walls and the nature of their location has considerable to do with the quantity of steel necessary to prevent cracking.

I do not know of any experiments having been made as to earth-weights. Where we use clay we use about 110 lbs. and in some cases where we expect shale to be mixed with it we use 120, where there is a considerable portion of the shale. Unless the variation was considerable I do not believe it would affect the design very much.

Mr. L. P. Blum: There was one wall shown separating a street from a park, almost circular in form. Was any allowance made for the arch effect of that wall? If not, could an allowance not be reasonably made for that arch effect?

The Author: The wall was not built in that shape for the sake of providing additional strength, but was required from the nature of the layout of the work. The quantity of vertical steel could be reduced by taking into consideration the arching action of the wall, but the sections of concrete could not be reduced, since they are determined by clearances required for erection. By providing some longitudinal reinforcement, we could utilize the arch action to a greater extent. In the design, however, we used only sufficient longitudinal reinforcement to prevent cracking under shrinkage and temperature stress. I think in this design, it was more economical to design the wall as a cantilever than to place any reliance on the arch action.

Mr. R. B. Woodworth: This has been a most interesting and most valuable paper. If there is any subject in engineering on which there is a very large amount of theory and very little exact science it is the subject of the designing of retaining walls and of earth pressures generally.

The paper on Earth Pressures and Bracing, read by Mr. J. C. Meem before the American Society of Civil Engineers and published in Vol. 33 of the Proceedings, to which Mr. Reppert referred, is coming to be recognized as one of the classic references on the subject, especially when taken in connection with the discussions thereon which were fully printed in Vol. 60 of the Transactions. The formulas and considerations presented in the original paper and in the discussions have done very much to indicate the importance of the subject and to crystallize information as to the best methods to be followed in retaining wall design.

The subject is of much interest, therefore, and I think we have all profited by the discussion which Mr. Reppert has given us, especially as his paper contains information on methods and cost of construction in our own locality. It is extremely convenient to have the data brought together in one place for ease and convenience of reference, and it seems to me that the paper will be most useful to the engineers of this locality in matters of design in the future, and Mr. Reppert well deserves the gratitude of the Society for the pains and labor the composition of such a paper necessarily entails.

The paper dealt only with retaining walls of masonry or concrete, both massive and reinforced. It might be well in this connection to point out that there are a number of retaining walls in the City which have been constructed by the use of other materials. The retaining wall of the Farmers Bank Building, for example, which prevents the street from slipping into the basement of the building, is constructed of 15 in. I-beams set vertically and having brick arches between. The significant fact in connection with this wall is that it was built in two stories separated by 24 in. beam and plate girders set horizontally at the level of the mezzanine floor into which the retaining wall beams frame, and the pressure from the street at this level was carried directly into the columns and floors of the building by struts in the mezzanine floor.

Where the wall is low and esthetic considerations do not require an ornamental or massive structure, retaining walls may be very economically constructed by the use of steel sheet piling

driven with an ordinary pile driver. Retaining walls of this character are becoming quite frequent in the construction of the foundations of large buildings, a conspicuous example being the use of interlocking channel bar piling in the retaining wall for the Railway Exchange Building in Chicago, and another being the retaining wall in the Pope Building at Cleveland composed of sheet piling. One advantage of the use of this material is the certainty with which the percolation of water may be prevented.

Mr. Edward Godfrey: I would like to make a few comparisons as to the matter of reinforcing the rib in retaining walls.

If the case were a horizontal slab projecting out from a wall as shown in Fig. 7, how many engineers would make the rods run like those shown at *A*? Wouldn't it be the more rational way to design it with rods anchored in the slab and in the wall?

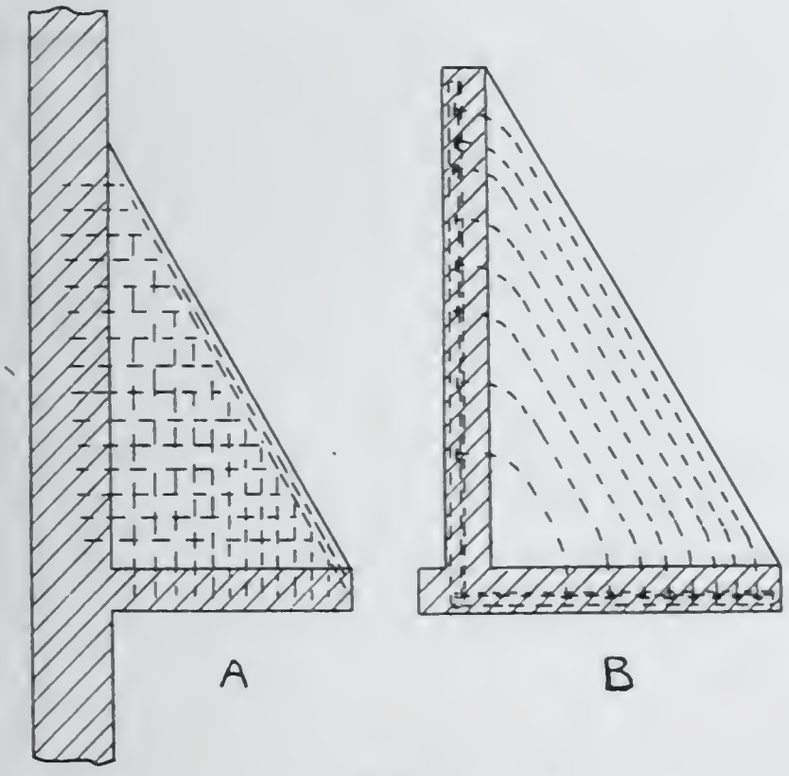


Fig. 7

Now we have the same conditions in the retaining wall at *B*. A lot of earth is on the slab that projects from the wall. The front wall corresponds to the vertical wall in a building. The stability of the vertical wall takes the place of the earth

pressure against the curtain wall of *B*. You might waste a whole lot of rods vertically and horizontally where a few rods anchored in slab and wall would answer every purpose. And yet engineers of wide repute have said that *A* is just as efficient as *B*. How many engineers would hang a slab of concrete on the projecting ends of lot of little rods and claim that was just as efficient as rods anchored in a shelf angle in that slab? It is something that would be good to think about.

MR. J. D. STEVENSON: Are not the stresses excessive in the rods in the back of the wall, as shown in this last diagram, or would you have sufficient strength in the rib to carry this excess in the back.

MR. EDWARD GODFREY: You can proportion the rods for whatever the pressures may be.

MR. J. D. STEVENSON: You have a relation between the front of the wall and its base; the two tend to pull apart. The two should be balanced to prevent overturning.

MR. EDWARD GODFREY: The deciding factor would be the weight on the slab. If we have rods to take the weight on the slab it will be sufficient.

If there is excess it would not matter. The excess rods would run up near the top of the wall and take the extra thrust of the backing due to frost.

MR. J. D. STEVENSON: Have you excess rods in the back of the rib?

MR. EDWARD GODFREY: You would have if the weight on the slab were the criterion. The weight of earth on the slab is far more than the horizontal pressure against the front curtain wall. You have the same rods in both cases.

MR. J. D. STEVENSON: You have the same rods in both cases, but you have a relation between the floor and the front of the wall; the two tend to pull apart and in case excess loads are thrown on the wall, will cause the rib to act as a cantilever. Owing to the monolithic character of the rib construction, the rib probably under all loads acts as a cantilever thereby throw-

ing the maximum stress at the back, and, for economical reasons requires the placing of the reinforcement as near as possible to the back of the rib. The floor and the front of the wall are held together by the rods in the rib. The stress, if any, in the rods nearest the toe will not be as great as those in the back of the rib.

Has the rib sufficient area so that more bars can be placed down the back of the rib?

MR. EDWARD GODFREY: The bars can be spaced to suit the location and intensity of the load on the slab.

MR. J. D. STEVENSON: That can be done providing the rib is wide enough. Excess width in the rib would reduce the economy of the design.

THE AUTHOR: The method of reinforcing ribs in the manner described by Mr. Godfrey was discussed in an article* by Mr. Godfrey within the last two or three years. It appears to me that this type of reinforcement of the rib would cost more than the arrangement shown in the design for the Dilworth Street wall. Mr. Whited used a type somewhat similar to that proposed by Mr. Godfrey in the design of a very high wall, the Melwood Street retaining wall, which was described before this Society in a paper by Mr. Whited. If we knew how the pressures were going to be applied, their amount and intensity, I believe that in some cases the arrangement proposed by Mr. Godfrey might be economical, at least as far as the quantity of materials is concerned. The cost of placing steel and concrete when the reinforcement is placed as proposed by Mr. Godfrey would be, I think, considerably more than the other arrangement. It is usual in such a design to thread the ends of the rods and to pass them through structural members and secure them with washers and nuts. The rods are also curved at each end and when placed in the rib they interfere with the placing of concrete. The inclination of the rods causes a loss in economy and, aside from the theoretical consideration of the question, I believe the cost of construction would be much higher.

The amount and intensity and point of application of the lateral thrusts is known only approximately and provision must

*Engineering News, Vol. 56, 1906, p. 402.

be made in most designs for thrusts in excess of those ordinarily expected. The actual distribution of pressures over the back of the wall or the front wall of a rib wall is not known; sometimes you may get the maximum pressure at or near the top in any given case. There is always some doubt as to what conditions you are going to run up against. For most retaining walls since definite knowledge can not be had as to the character of the material, the design shown in the details of the Dilworth street wall is safer and at the same time more economical. For a carefully placed fill of sand or cinders or for a fill composed of materials with little cohesion, approaching liquid pressure, it is possible that the type of reinforcement proposed by Mr. Godfrey might be the more economical. For retaining walls where the fill consists of loam, clay, shale and conglomerate materials, in which case excessive pressures are likely to be developd by bodily slipping or tilting over of the earth mass, the design of the rib as a cantilever possesses a much greater factor of safety and secures the most economical placing of the materials.

Mr. Edward Godfrey: Independent of the nature of the fill you have a shallow slab and a heavy pull on your vertical rods, which must be anchored in that shallow depth, because of the weight of earth on the rods and quite independent of its character. This is the difficulty. With rods placed as at *A*, you have but the short ends of the rods for anchorage, where with an anchoring bar as at *B*, you make a shelf for the slab to rest on and get anchorage in the front wall of the same nature.

The Author: In any case if you have not sufficient diagonal reinforcement in the ribs to withstand the strains caused by the loading, your diagonal reinforcement will fail, since your rib will act as a cantilever, and, to make the wall safe, sufficient reinforcement should be placed in the back of the wall where it is most effective. Illustrating this, if you have a stress of 15000lb in the diagonal rods in the back of the wall, the stress in the diagonal rods near the front of the wall will be very small or in compression. The rods are liable to

fail successively from the back of the wall toward the front resulting in the failure of the wall.

Mr. Edward Godfrey: The diagonal reinforcement can be made just as effective as required by spacing the rods close where the pressures are greater, but what is the use of employing a lot of short rods that cannot possibly be anchored for their full value? And why overlap these rods and double up on their length when they could be united, with a large saving of steel? The placing of 30 or 40 short rods is far more troublesome than placing and holding in place the harp-like reinforcement shown at *B*.

LOW PRESSURE STEAM TURBINES

By F. E. McKee*

Turbines designed to operate on the exhaust steam from reciprocating engines, have excited much interest during the past year and many papers have been written on the so called low pressure turbine. In fact, the economy to be realized in their use is so great that it is difficult to convince the average person that the claims are not visionary. The low pressure turbine today owes its existence to its ability to utilize the waste or exhaust steam from inefficient engines, and so improve the economy of the power system. In many plants where a low pressure turbine has been added to run on waste steam, the proposition has proven to be almost as attractive as a water power plant.

The steam turbine was introduced into this country and placed on a commercial basis about ten years ago. The use of the turbine has become so general that the question today, in considering new power house equipment, is not always whether the prime movers will be engines or turbines, but rather which type of turbine will be most suitable for meeting the prevailing conditions. The low pressure turbine has come into prominence in the United States within the past two or three years. The first record we have of an exhaust steam turbine installation was the one at the Buray mines in France designed by Professor Rateau in 1901. This plant was completed in 1902 and is still in successful operation. For several years Professor Rateau confined his work to the continent and installed many machines in industrial plants. The units were usually small, averaging 300 horse power. Professor Rateau's work was mainly in steel mills and mines and he brought out his regenerator in order to

*Assistant Manager, Shaw Electric Crane Co., Muskegon, Mich.

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use steam from engines operated intermittently. In this country we have been somewhat slow in seeing the great possibilities of the low pressure turbine. The high price of coal in England and on the continent has spurred on the development of the low pressure turbine and great progress has been made. Independent companies have been organized to purchase the exhaust steam from industrial plants for use in generating electrical energy which in turn is sold to users of power, in some cases back to the same companies from whom the exhaust steam was obtained.

The low pressure turbine is not, strictly speaking, an independent source of power. It is rather an auxiliary to other steam driven engines. In order to take advantage of the rapid and continued improvements in the design of prime movers, central stations found it necessary, up to the advent of the steam turbine, to make very radical changes in the existing equipment and often to entirely discard apparatus of high cost long before its condition warranted such action. The old type belted units gave way to the direct connected equipment and these in time were replaced by steam turbines. The introduction of the steam turbine brought about the most radical changes in power house design, not only as to the prime movers alone, but as effecting the auxiliary equipment as well. These changes have all tended toward the reduction in the size of power houses for equal capacity. Now comes the low pressure turbine and it does not exact that much radical changes be made in order to obtain improved results. It is not necessary to discard old apparatus or make any great changes in the operating conditions to take advantage of the saving offered by the use of a low pressure turbine. It does require that additional space be provided. The low pressure turbine can be used in connection with the most antiquated steam engine installation and greatly improve the economy of the station.

The low pressure turbine is therefore very attractive to central station owners as it increases the capacity of the station, reduces coal consumption and effects all with a lower cost of investment than would be the case if modern high pressure appa-

ratus were installed. Take for example an existing steam engine plant. If no additional capacity is required, which is very seldom the case, the low pressure turbine in connection with the old equipment will reduce the coal consumption, and permit of the shutting down of part of the engine plant. If more capacity is required it can be secured through the low pressure turbine without proportionately increasing the fuel consumption. The field for the low pressure turbine is a very large one and industrial plants and street railway companies are rapidly becoming interested in the low pressure turbine as a means for improving their operating conditions. Numerous reports and tests have been made covering a wide variety of operating conditions, and this information is in most cases available. It is not the purpose of this article to go into the design of different makes of turbine or to give details of tests made, but rather to treat the subject in a general way as influencing the modernizing of already existing engine plants and the design of new installations.

Power stations using reciprocating engines and low pressure turbines can be divided into three general classes as follows:

CLASS 1. Where the steam supply is decidedly intermittent as in the case of reversing mill engines. The turbine in this case is generally used to furnish power independent of the engine.

CLASS 2. Where the steam supply from the engine is uniform, as in the case of an engine running on constant load or where a number of different engines are connected to a common exhaust main.

CLASS 3. Where the steam supply and the load on the turbine vary together as in the case of street railway stations.

In Class 1 are included all engines operating rolling mills, mine hoists and other intermittent loads. Engines of this class are usually operated non-condensing, the steam being allowed to pass into the air. The saving therefore due to the low pressure turbine is clear gain, and there will be developed in the turbine practically the same amount of power as has already been fur-

nished by the mill engine. To obtain the best results, the low pressure turbine should be supplied with steam at a uniform rate of flow, and therefore it is necessary in order to use all the steam furnished intermittently by engines of this class to provide some form of heat storage.

In Class 2 are included the majority of central stations which furnish power for lighting and factory drive. In this case the quantity of steam is more uniform. As long as the supply of exhaust steam is enough to operate the turbine at all loads, or if the turbine is only required to furnish power in proportion to the exhaust steam supply, no heat storage is necessary. If the peak load on the turbine demands more steam than the engine can supply, a regenerator could be used to advantage, providing the peak duration is not for any length of time, otherwise live steam would have to be admitted to the turbine.

In the case of Class 3 the turbines are unsually connected to the same bus bars as the generator driven by the engine, and therefore the load on both units rises and falls together. This condition does not require the use of a governor on the turbine as it is floateing on the line in parallel with the engine driven unit. In this case a regenerator is not so necessary, although, if the load varies rapidly, a storage of heat energy would undoubtedly show a saving in operation. The above three classes must be considered quite general as each individual case offers a special problem and must be given careful study. Further complications exist wherever the output from the engine and the requirements of the turbine vary independently; e. g., the turbine may be called upon for heavy duty at the same moment the supply from the reciprocating engine is a minimum, or vice-versa.

As mentioned above the best results are obtained from the low pressure turbine when the steam supply is uniform or non-intermittent. In the case of a uniformly loaded reciprocating engine, or where a number of engines exhaust into the same low pressure turbine, the flow of steam may be quite uniform and a definite length of connecting pipe may be all that is necessary to eliminate the engine pulsations. The size of the regenerator is

determined by the time element in supply and demand, and due consideration must be given to the periods between maximum and minimum supply. No low pressure turbine discussion is complete without some mention being made of regenerators, and it can be said, as a general statement, that every low pressure turbine installation involves at the same time the consideration of a regenerator. The regenerator or accumulator consists of a large closed vessel or tank partly filled with water, so designed that the entering steam either passes through the water, as in the case of the Rateau type or mixes with a water spray in a separate space as in the case of the American regenerator. In the latter type, the water from the bottom of the main tank is injected into the jet of incoming steam which sets up a circulation and tends to maintain a uniform temperature of the water in the regenerator.

The function of the regenerator is two-fold. First, it stores up heat when the engine is exhausting more steam than the low pressure turbine requires; and second, it gives up steam to the turbine when the supply of exhaust steam is insufficient to carry the load. It thus acts as an equalizer in the steam line, and has been referred to as a heat fly-wheel. It can also be compared to a storage battery which floats on the line to carry a power station over the peak loads. The regenerator is usually operated at about atmospheric pressure, or, to avoid a vacuum on the exhaust line, slightly above atmospheric pressure. The steam exhausted from a reversing mill engine varies in amount through a wide range, often from a rate of 2,000 lb. per hour to a rate of 160,000 lb. per hour. It is therefore very plain in such cases that some kind of an accumulator is necessary. With the ordinary rolling mill engine the periods of small steam supply are usually from one to three minutes in length, and the regenerator must be of such capacity as to tide the turbine over the periods of minimum supply. The regenerator is usually rated at such a capacity as will deliver steam of a definite number of pounds per hour for a certain definite period, when all sources of steam are shut off from the regenerator.

There are very few auxiliaries used in connection with a re-

generator. A water trap is provided to take care of the excess of water of condensation, also a relief valve which relieves the pressure in the regenerator when it reaches a predetermined value. This valve prevents any back pressure on the engine. A live steam reducing valve is often placed on the regenerator to admit steam from the boiler in case the supply of exhaust steam falls off for a longer period than the capacity of the regenerator will provide for. Also in many installations a receiver is placed in the exhaust line between the mill engine and the regenerator to absorb the steam shocks and thereby reduce the strain on the regenerator. The receiver is a tank containing baffles and if made of proper size will also reduce the back pressure on the mill engine. An atmospheric relief valve is generally placed between the engine and the receiver, which permits the steam to pass into the air when there is more than is required by the regenerator, or when the engine is operated non-condensing. The steam flowing to the regenerator will usually have a temperature near 212 deg. fahr., and the mass of water will be heated to the same temperature. The regenerator is thus a boiler working at atmospheric pressure, and if the supply of exhaust steam diminishes, the regenerator will give steam to the turbine.

The fact that steam at atmospheric pressure when expanded down to 28 inches vacuum yields about the same energy as steam expanded from 150 lb. pressure to atmosphere, is more appreciated since the advent of the low pressure turbine. In a non-condensing engine the energy in the steam below atmospheric pressure is wasted, while in the case of condensing engines this energy is not used to the best advantage. The gain in operating condensing as against non-condensing is not much over 20 per cent., and for such a gain it is often found to be unprofitable to install a condensing plant, especially if the water is raised any great distance. A reciprocating engine is very efficient when operating between boiler pressure and atmospheric pressure, but quite the contrary when operating on pressures below atmospheric. In a reciprocating engine the final pressure of discharge depends on the volume to which the steam is allowed to expand. The most efficient triple expansion engines expand

the steam about thirty times, while the average compound engine has an expansion ratio of about 15 to 1. The triple expansion engine discharges the steam at about six pounds absolute. A vacuum of 28 inches corresponds to about one pound absolute pressure and if the expansion was continued until a pressure of one pound was reached the ratio of expansion would be 96 to 1. It is not commercially practical to design an engine to meet these conditions and consequently we are generally satisfied with obtaining a 26 inch vacuum on a reciprocating engine, as the limit placed on the ratio of expansion makes it unnecessary to maintain high vacuum in order to obtain the best engine economy.

The low pressure turbine is especially efficient when operated on pressures below atmosphere. The expansion is complete and the full benefit can be obtained from the use of high vacuum. The low pressure unit is the simplest form of turbine, and unlike the high pressure turbine or engine, is not subjected to severe temperature and pressure changes. It will be seen from the foregoing that the most efficient power unit would therefore consist of an efficient reciprocating engine exhausting into a low pressure turbine of proper size which in turn will discharge into a condenser operating at high vacuum. As stated previously the low pressure turbine will about double the output of the non-condensing engine without any increase in the boiler capacity. When the low pressure turbine is placed between an efficient compound condensing engine and a condenser, the steam economy will be improved over that of the condensing engine by between thirty and thirty-five per cent. The following example of a combined engine turbine unit shows clearly the possibilities of such a unit. The engine is direct connected to a 1200 k. w. generator and develops a kilo-watt hour on 32 pounds of steam when operating non-condensing at full load. The total steam required non-condensing is therefore 38 400 lb., and allowing 8 per cent. for moisture, we will have 35 328 lb. of steam at approximately atmospheric pressure for use in the low pressure turbine. A 1000 k. w. turbine gave on a test a steam consumption of 34.7 lb. per kw. hr., therefore with the above steam it would devel-

op 1018 k. w. Adding this to the output of the engine, we have a total of 2218 k. w. generated from 38 400 lb. of steam or at the rate of 17.3 lb. of steam per kw. hr. The addition of the low pressure turbine thus added about 85 per cent. to the capacity of the station without increasing the amount of steam used. This particular engine was designed for condensing service and when operating at 28 inches vacuum developed a kilowatt on 23.2 lb. of steam. Therefore with the same steam per hour, the engine running condensing would generate 1655 k. w., or 455 k. w. more than when running non-condensing. The addition of the low pressure turbine would add 563 k. w. to the capacity of the condensing unit or about 35 per cent. without any increase in the steam consumption. The average condensing engine does not operate with equally good economy under a variable load, that is, the engine is operated at poor economy when either under-loaded or over-loaded. The efficiency of a low pressure turbine is quite uniform throughout a considerable range of load and it is therefore seen that the effect of a combination of engine and turbine is to give a more uniform economy for all loads. In fact in the above example the water rate does not vary over a pound when operating between three-quarter and one and one-quarter full load. This fact is of great importance as there are very few stations where it is possible to operate engines under constant load. In stations composed of a number of engine units each capable of efficient operation, it is often found that the total water rate of the station is anywhere from 30 to 40 per cent more than that of each individual engine when running at full load. This question is therefore a very live one for central stations, as the gain from the use of a low pressure turbine is in most cases a very welcome addition to the station capacity.

The recent improvements carried out by the Pressed Steel Car Company at their McKees Rocks Works is typical of what can be accomplished towards improving the operating conditions of a power system, while the new plant of the Phillips Sheet & Tin Plate Company at Weirton, near Steubenville, is an example of the low pressure turbine installed as part of the original equipment of a new plant. The author was actively connected with

both of these undertakings and a brief outline of each may be of interest.

In the summer of 1908 the Pressed Steel Car Company were called upon to provide additional electrical power to operate new shop equipment and extensions, and the conditions were such that required thorough investigation. Up to this time all power units were operated non-condensing. The equipment consisted of four simple direct current engine generator units and two 500 k. w. A. C. high pressure turbine units, in addition to a number of hydraulic pumping engine and air compressors. Both the boiler house and the engine room were very much congested and there was practically no room for either additional power units in the present buildings, or for the extension of the buildings. It was plainly understood at the start, that any consideration of improving the power economy would include some arrangement for utilizing the exhaust steam from all the small engine generator sets, hydraulic pumping engines, and air compressors. The exhaust from the con-condensing units, being discharged to atmosphere, represented a great waste even after deducting the exhaust steam required for heating the buildings and the boiler feed water. The selection of equipment to furnish additional power, together with the betterment of the then existing operating conditions, narrowed down to either of the following two arrangements:

FIRST: The installation of additional high pressure turbines with complete condensing plant, for both the new and old turbine units.

SECOND: The installation of a low pressure turbine, together with enough high pressure turbine capacity, that would, with the old units, constitute a sufficient high pressure plant to handle the load in case the low pressure unit was, for any reason, out of service.

The subject of gas engines, as prime movers for additional power units was not given very much consideration on account of their high initial cost, large floor space required, and the fact that with low priced fuel their economy is not as good as the high

pressure turbine. The independently governed low pressure turbine, was, at this time, a comparatively new development, and after being convinced of its reliabality and economy it did not take long to decide on its use in preference to the high pressure turbines. As mentioned above, in order to increase the plant economy as a whole it was absolutely necessary to make some use of the energy in the exhaust steam from the many pumping engines and compressors, and this meant some form of compounding and condensing. The miscellaneous units were not designed for condensing operation, and many were of quite old types. By installing the low pressure turbine to run on the exhaust steam from all the separate units, the use of the turbine would really amount to compounding all the non-condensing units—practically using one low pressure cylinder for a number of simple engines.

A highly efficient condenser could then be used in connection with the turbine and we would be "getting something for nothing" if you consider that prior to the use of the low pressure turbine the exhaust steam was thrown away. Another very important consideration was that additional boiler capacity would have to be provided if high pressure turbines were installed, thus making the high pressure proposition about 30 per cent higher in first cost than the low pressure equipment. Also with the high pressure turbine installation, the exhaust steam from the several pumps and compressors would still have been thrown away.

In order to determine the size of the low pressure unit, it was necessary to ascertain the amount of exhaust steam available after heating the shops and feed water. Complete tests were made of all non-condensing engines, pumps and compressors when operating under normal shop conditions, and the total steam consumption computed. Knowing then the amount of boiler steam required for all purposes, it was comparatively simple to figure the exhaust steam required for heating the feed water, and the amount necessary to heat the buildings was found both by test and computation. The results were as follows:

Total steam required by non-condensing engines	111 400 lb.
Exhaust steam available, allowing for 8 percent moisture	102 500 lb.
Exhaust steam required for heating	38 000 lb.
Exhaust steam required for boiler feed	25 500 lb.
Exhaust steam available for turbine	39 000 lb.

The turbine builder guaranteed a water rate of 38 lb. per kw. hr., and at this rate there was sufficient steam for supplying a 1000 k. w. unit. Of course it is understood that the demands of the heating system vary and during the summer months, there would be an additional quantity of exhaust steam, 38 000 lb., available, which, at the above rate, figures out another thousand kilowatt. As the first machine would be installed during the summer of 1909, ready for operation during the winter months, it was finally decided to purchase one 1000 k. w. unit at once, and a second unit after the first one had been successfully demonstrated. A 625 k. w. high pressure unit was installed at the same time, bringing the station capacity up to 2625 k. w.

During the month of October, 1909, the first month throughout which the 1000 k. w. low pressure turbine was operated, almost the entire output was furnished by this unit and the results obtained were very gratifying in that all expectations were more than fulfilled. It is not necessary to give detailed figures, but the results obtained will be sufficient for present purposes. The cost of operation per kilowatt hour of output, including the fixed charges on the value of the entire station, was .0047¢, and a saving of $2169.75 in fuel alone was realized. At this rate, the saving in fuel for a year would amount to a total of $26-037 00. As the plant was formerly operated non-condensing, this saving can be considered as due to two separate improvements: First, to the condensing plant, and second, to the low pressure turbine. In the detail figures, the former was credited with $14-451 00 and the latter with $11 586 00. The cost of the low pressure turbine and condenser plant completely installed, without including any amount for building, was close to $75 000 00, therefore we have for the first year a gross saving of nearly 35 percent., which is very close to the original estimate of 33 percent. made before the improvement was commenced. If we allow 12 percent. to

cover depreciation, interest and maintenance, we would have a net saving of 23 percent., or $17 037 00. It is to be remembered that this saving is based on one month's performance, and one of small total output, therefore it is only reasonable to expect that the saving will increase as the load on the station increases. The introduction of the low pressure unit, made it possible to shut down two 500 k. w. high pressure turbines, and about 2250 h. p. of boilers, and there were other beneficial items that are hard to capitalize. The second low pressure turbine of 625 k. w. capacity has been installed and the entire station load is now being carried on exhaust steam turbines, operated by steam previously permitted to go to waste. These results certainly call for some attention, and show what can be accomplished with old power equipments. Complete tests of the entire equipment are in progress, and a further and more detailed report will be available in a few months.

The Weir Plant of the Phillips Sheet & Tin Plate Company is probably the first to install a low pressure turbine as part of the power equipment for a new mill. This plant has just lately been placed in partial operation, and the subject of power was given thorough consideration. Coal is used exclusively for fuel and the boiler plant is designed for 175 lb. steam pressure. The principal elements of load in any tin mill are the hot mills and the cold rolls, and the following methods of drive were considered:

FIRST: To drive both the hot mills and cold rolls by motors, installing a high pressure turbine plant for furnishing the power.

SECOND: To drive the hot mills by a condensing engine and the cold rolls by a motor, installing a high pressure turbine equipment to furnish power for the cold roll motor, as well as other small motors and lights throughout the plant.

THIRD: To drive both the hot mills and the cold rolls by condensing engines, and providing an engine-generator set large enough for the various small motors and lights.

FOURTH: To drive the hot rolls by a non-condensing engine, exhausting same into a low pressure turbine, which in turn would furnish electrical power to drive the motor on the cold rolls as well as the other motors and lights.

After thoroughly considering each scheme the choice narrowed down to between the first and fourth arrangements, the latter finally winning out, because the engine-low pressure turbine unit promised about 8 percent better economy than the straight high pressure turbine proposition. To install condensing engines on such loads as hot mills and cold rolls, where the load is so variable, would necessitate very large condensers, to take care of the sudden and heavy exhaust puffs from the engine when the rolls are working the hardest, i. e. just starting a pass. It is of course understood that the usual tin mill load does not vary between such wide limits as does a reversing engine driving a rolling mill, for in the former case there are several mills in the train, and it is not likely that all the mills will be working up to capacity at the same instant, therefore the tendency is to keep the load variations within closer limits. Again, as already pointed out, the vacuum with condensing engines would not exceed 25 inches, probably nearer 23 inches, and therefore the steam consumption would not compare at all favorably with either the high pressure turbine or engine-turbine unit. The original plant was laid out for ten hot mills driven by a 32 by 54 by 60 twin tandem compound engine running at 28 r. p. m. The engine was direct coupled to the roll train, five mills being placed on each side. A 600 h. p. induction motor was decided upon to drive the cold rolls.

On account of the fluctuating nature of the engine loads, the steam supply to the low pressure turbine would be very irregular and a regenerator would be desirable. To obtain some idea of the amount of steam that would be consumed per hour by the engine, and just how the quantity would vary for a given period, a test was made upon a similar installation consisting of a 36 by 72 Corliss engine driving eight hot mills. It was found that the power developed varied from 100 to 2000 h. p. during

two consecutive revolutions, and the average horse power for sixty-eight consecutive revolutions, was 735. These results show plainly that a regenerator should be considered. From the data derived from this test, it was decided to install one 750 k. w. turbine of the mixed pressure type. A unit of this capacity would carry the entire motor load of the plant, and in case of emergency or temporary shut down of the mill engine, the turbine could be operated on boiler steam. This unit will develop full load with all low pressure steam, with all high pressure steam, or with any proportion of steam of each pressure. A small engine-generator set was also installed for use during time of light-load, or whenever the hot mills and cold rolls were not running. A conservative estimate indicated that the engine-turbine combination should develop a b. h. p. on 14.5 lb. of steam, which corresponds to a rate of 20.5 lb. per kw. hr. Subsequent tests will be made when the plant is in full operation.

The foregoing installations were both of moderate size and it may be of interest to refer briefly to the 7500 k. w. low pressure turbines recently placed in service by the Interborough Rapid Transit Company of New York. The details of this installation, as well as the complete tests made on the combined engine and turbine, are admirably treated in M. H. G. Stotts paper read before the American Society of Mechanical Engineers. The need of additional power was felt by the Interborough Company at their subway plant and every available scheme was thoroughly investigated. The station contains nine 7500 k. w. engine generator units and three 1250 k. w. turbine units, the latter only being used for lighting. The engines were of the Manhattan compound condensing type, exhausting into barometric condensers. After fully considering water power transmission, gas engines, additional condensing engine units, high pressure steam turbines and low pressure turbines in connection with present engines as the different means for providing the additional power required, it was finally decided to install the low pressure turbine and the initial order was for one 7500 k. w. unit; but two additional 7500 k. w. units have since been added. The transmission of the power from a hydraulic plant was rejected on account of the high cost

of transmission lines and the unreliabilty of the service. The gas engine was abandoned on account of high cost and maintenance, while the high first cost and small economical range eliminated the reciprocating engines. As is generally true in a proposition of this kind the choice was finally between high pressure turbines and low pressure turbines, and in this particular case there was enough space in the power house building to accommodate either type of unit. On account of lower first cost to install and a better operating economy, the low pressure turbines were purchased and final tests show the wisdom of the choice.

Mr. Stott summarizes the net results as follows:

FIRST: An increase of 100 percent. in the maximum capacity of the engines.

SECOND: An increase of 146 percent. in economic capacity of the plant.

THIRD: A saving of approximately 85 percent. of the condensed steam for return to the boilers.

FOURTH: An average improvement in economy of 13 percent. over the best high-pressure turbine results.

FIFTH: An average improvement in economy of 25 percent. between the limits of 7000 k. w. and 15 000 k. w., over the results obtained from the engine units alone.

SIXTH: An average unit thermal efficiency between the limits of 6500 k. w. and 15 500 k. w. of 20.6 percent.

These results are remarkable and the combined 15 000 k. w. units are now probably unsurpassed in point of economy.

In view of the universally satisfactory results obtained from low pressure turbines, no two installations being exactly alike, any power station of reasonable size operating reciprocating engines should become interested in this method of compounding the engine equipment. The application of low pressure turbines is flexible and can be used in connection with most any existing engine plant with remarkable results. The size and design of engines, nature of engine load as well as general operating conditions, all influence the selection of the turbine and every case must be thoroughly considered in all its details. We hear much

today about the conservation of our natural resources, and steam which is now being wasted or used with poor economy can be considered as coming under this head. It should be clear that the low pressure turbine proposition is entirely reasonable as all results given can be verified.

DISCUSSION

F. G. GASCHE*: In reading over the paper by Mr. McKee it occurs to me that the author has had an opportunity to amplify some of the statements concerning turbine installations. Perhaps the intention was to allow these conceptions to develop in course of the discussion, and, in entire sympathy with the intentions of the author, I would submit the following observations:

Concerning the first paragraph, page 371, I would amend the statement by saying that an increased steam consumption at a given electric power plant does not necessarily follow an increased output when a low pressure turbine is added to the equipment. Alterations may be made in the engine such that while separately carrying a reduced load the actual steam consumption of both engines and turbine will amount to the same as the original conditions of engines. Simultaneously, the electrical output may be almost doubled in some cases. Concerning the last sentence on page 371, I would add the following:

Engines of the reversing rolling mill type as a rule give out enough steam to enable nearly double the amount of power to be realized in the more recent types of low pressure turbines. In making this statement I assume that the average power of the engine is estimated as the average energy delivery for a continuous hour's operation, and not the average of a set of cards unless friction loads are included. As the service of a low pressure turbine to all intents is continuous, and practically becomes such with the proper construction of auxiliaries and controlling apparatus, it is possible to make comparisons with unaided engine performances by adopting the proposed unit of measurement.

*Mechanical Engineer, Illinois Steel Co., Chicago, Ill.

In speaking of the "Class 3" turbine on page 372, I would suggest that the "complication" referred to indicates that the greatest load factor is realized by the use of the so-called "mixed flow turbine" involving as a rule but a small additional expense over the straight low pressure machine. With reference to the types of the low pressure turbines just mentioned I will endeavor to define the type of control that should characterize a true "mixed flow" turbine whereby it possess industrial and commercial advantage over all other types.

Suppose we have several engines exhausting into one common receiver or exhaust system, while the steam from this system flows to a low pressure turbine. The loads on the engines are to be variable; so, also, the amount of exhaust steam available to the turbine. The load on the turbine is to be variable and in no way dependent on the engines. If the low pressure turbine is a "mixed flow" machine it will accomplish the following results:

(a) Sustain its load without the admission of live steam either to the exhaust system or through reducing valves to the turbine, when the exhaust from the engines is just sufficient for the load on the turbo-generator.

(b) Admit enough live steam to high pressure chambers of a turbine to sustain the generator load and to make up for any deficiency of exhaust steam from the engines. Meanwhile the high pressure steam is usefully expanded into the high pressure turbine nozzles, and not wastefully through free expansion in reducing valves.

(c) When the exhaust steam from the engines fails the entire turbo-generator load is carried by high pressure steam usefully expanded in the several stages of the turbine from boiler pressure to back pressure.

(d) When, after the continuation of a heavy load on the turbo-generator, the exhaust from the engines again equals the turbine requirements, the high pressure steam will be completely cut off the turbine and not allowed to flow through reducing valves into the exhaust system.

With this understanding of the functions and capacity of a

mixed flow turbine I have little patience with the insistent advocacy of the straight low pressure machine for many applications particularly for rolling mill work. When we consider the small additional expense of the mixed flow equipment, and the earning capacity of a turbo-generator, always ready for emergencies, there is positively no excuse in refusal to demand mixed flow machines in the majority of cases.

If any man insists on the introduction of a straight low pressure machine in a rolling mill where he has a steady and

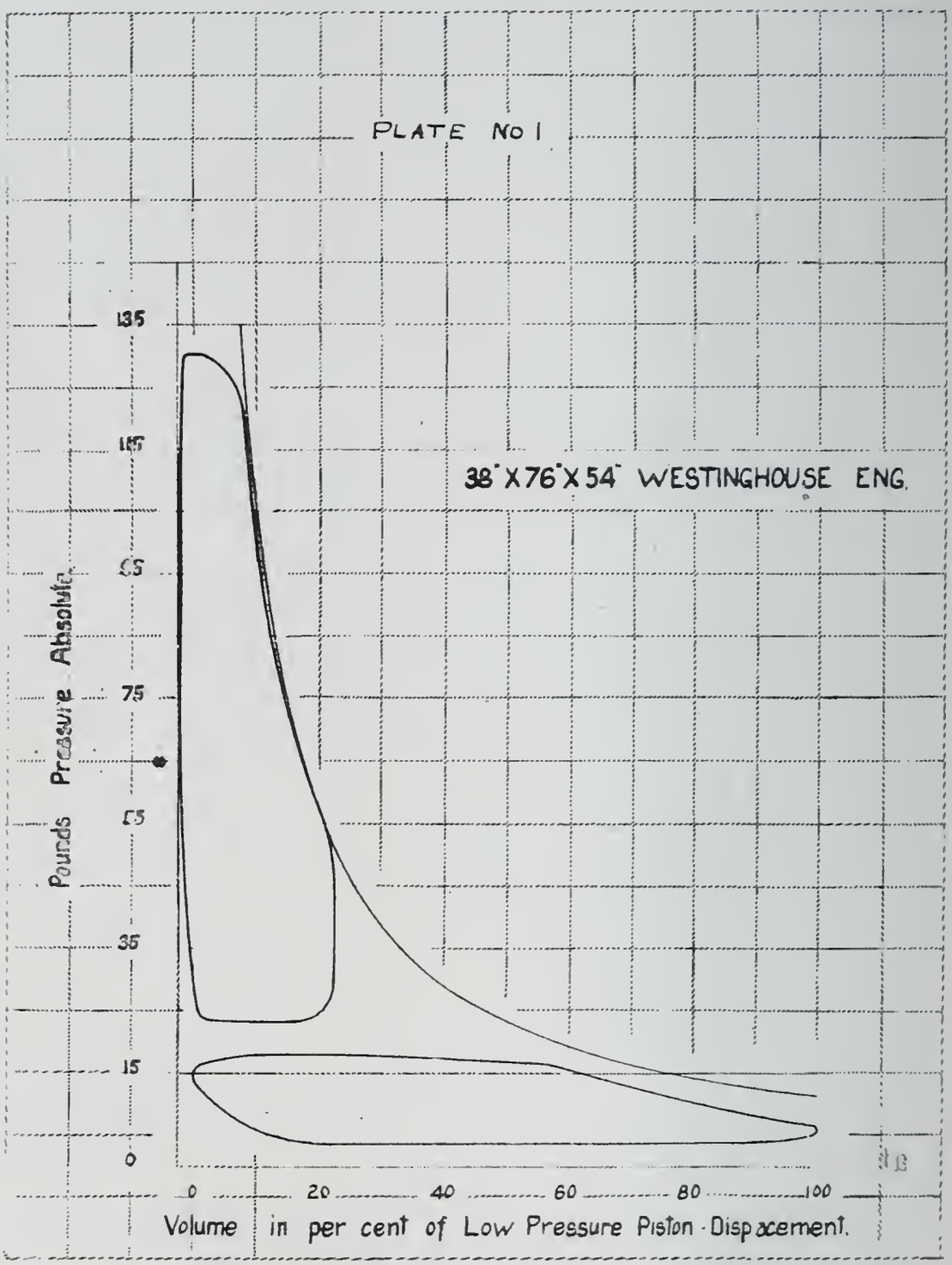

Plate No. 1

heavy demand for electric power when he might easily obtain the advantage of the mixed flow turbine, his case is almost as hopeless as the man who refused to buy a feed water heater because he "did not need his water so hot."

I would consider the points well taken in the second paragraph, page 373, but sufficient emphasis is not placed on the first requirement. Any closed tank of hot water will perform the second function at least once, but the time intervals for the storage of heat are frequently so short that the adequate structure must assume the functions and name of "regenerator." The action of a steam regenerator essentially requires a rise and fall of the temperature of the water. These temperatures correspond to the pressures of practically dry saturated steam in the Rateau type of apparatus, and follow closely all variations of steam flow to and from the regenerator.

I take exception to the first statement of the second paragraph of page 375 as the performance of low pressure turbine alone is not to take the precedence over the considerations performance of engine and turbine combined. With any construction involving the use of one low pressure turbine combined with several engines, I believe a superficial examination will show that there is a thermodynamic gain by indulging back-pressures on the engines somewhat higher than atmospheric pressure. The contrary should be the case when, exceptionally, a single electric generator engine delivers steam into a low pressure turbine without the intervention of a regenerator and the two generators electrically tied together. Aside from the thermodynamic gain from high back pressures in the general case there is the distinct practical advantage in avoiding air leakage into the exhaust pipe system.

The estimate of savings due to the application of low pressure turbines as given on page 375 is hardly an indication of the possibilities notwithstanding the qualifying conditions of "an efficient compound engine and condenser." While the following illustrations of a practical and operating case do not support my contention since the engines were not originally "highly

efficient'' they at least exhibit the appropriate methods of studying similar propositions for low pressure turbine installations.

Plate 1 shows the original steam distribution for a vertical cross compound engine constituting one of three separate and unlike units. This engine originally developed an average of 2755 i. h. p.

Plate 2 shows alterations of receiver pressures and various valve operations to avoid loops on the low pressure cards preparatory to exhausting to the turbine.

Under these circumstances and with the *same* amount of

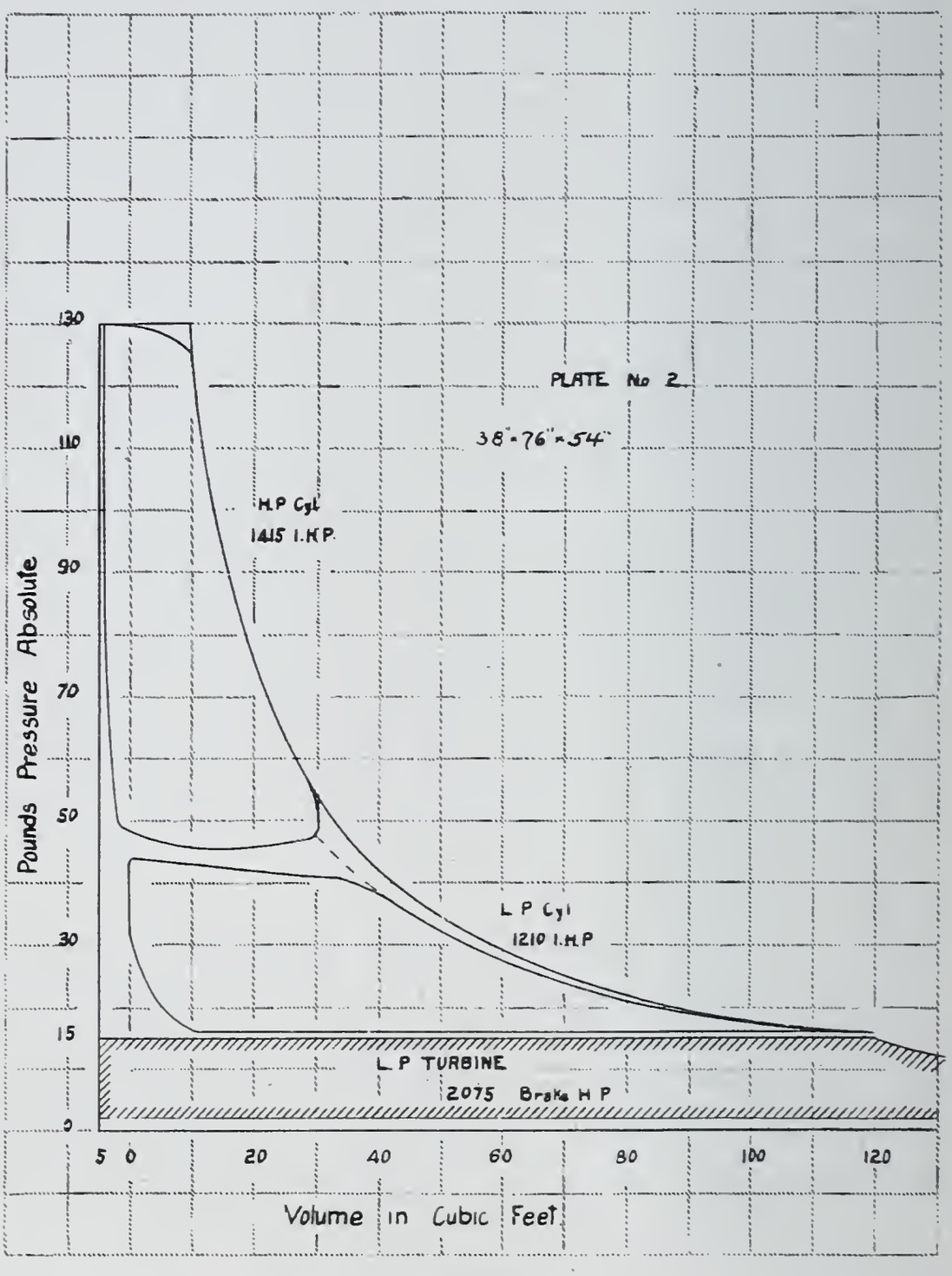

Plate No. 2

steam passing through the engine the energy realized from engine and turbine would be as follows:

High pressure cylinder	brake h. p. 1350
Low pressure cylinder	brake h. p. 1140
Turbine	brake h. p. 2075
TOTAL	brake h. p. 4565
TOTAL STEAM PER HOUR	Lbs. 51500
STEAM PER HOUR	per brake h. p. 11.28

Plate 3 shows combined cards for two double horizontal vertical cross compound engines with excessively large low pressure cylinders in vertical position. Each unit developed in the original condition about 2580 i. h. p.

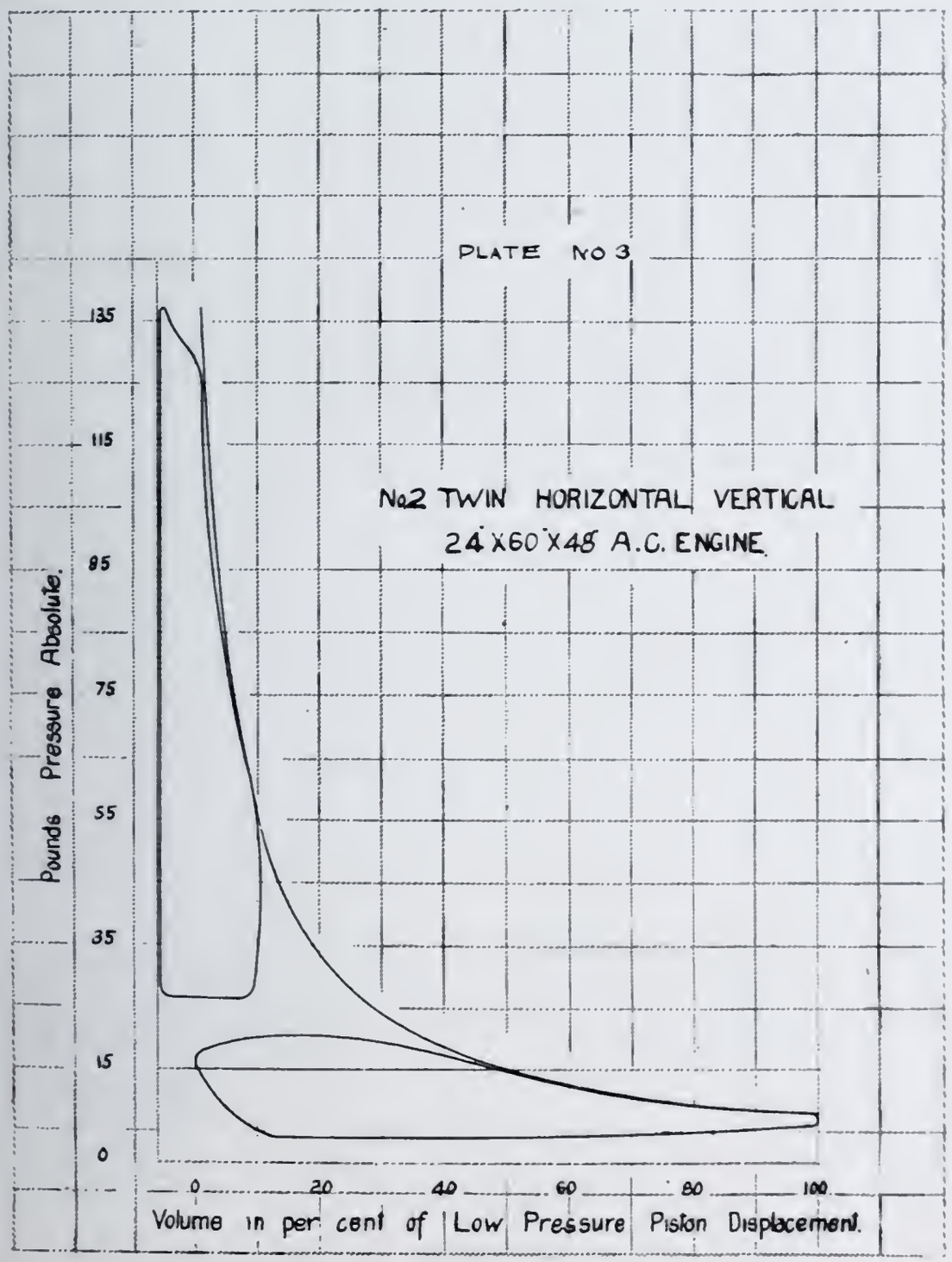

Plate No. 3

Plate 4 shows steam distribution with new low pressure cylinders suitable for noncondensing operation and the *same* amount of steam passing through the engines as for Plate 3. When thus modified each engine unit and low pressure turbine would exhibit the following performance, viz.:

High pressure cylinders .....brake h. p. 860
Low pressure cylinders .....brake h. p. 1244
Turbine ..... brake h. p. 2135
TOTAL FOR ONE UNIT .....brake h. p. 4239
STEAM PER HOUR PER .....brake h. p. 11.48

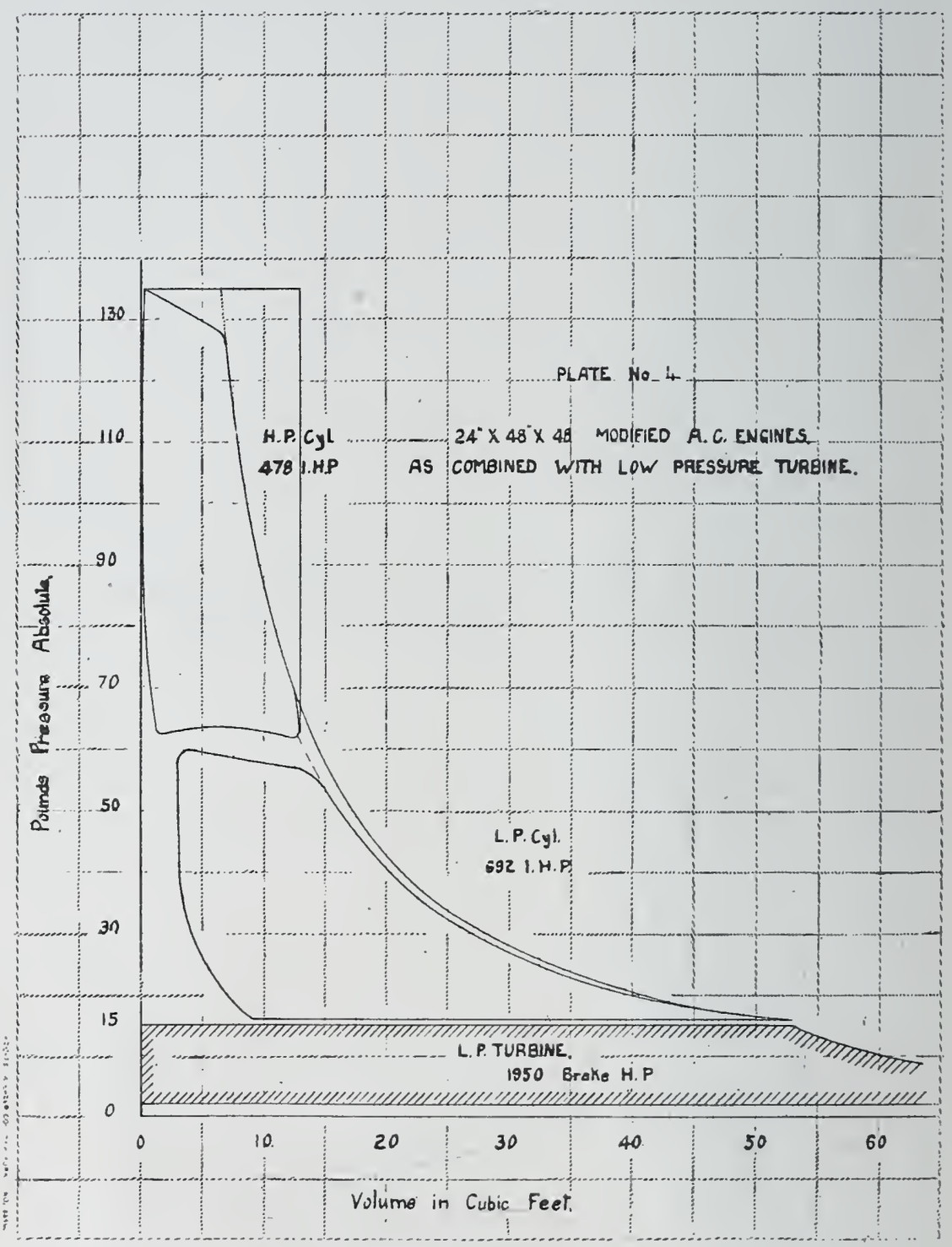

Plate No. 4

Plate 5 is an illustrative volume pressure diagram for the 24 by 48 by 48 inch engines but a different load condition than that shown for Plate 4. It is interesting chiefly in showing what enormous low pressure cylinders would be required to accomplish the same expansive use of steam as that realized with the low pressure turbine.

The entire plant will operate under the following conditions according to this study of the possibilities:

THREE STEAM UNITS	brake h. p.	6700
LOW PRESSURE TURBINE	brake h. p.	6345
TOTAL FROM THE PLANT	brake h. p.	13045
TOTAL FROM THE PLANT	K. W.	9740
STEAM PER HOUR	per brake h. p.	11.40
STEAM PER HOUR	per i. h. p.	10.70
STEAM PER HOUR	per K. W.	14.35

THERMODYNAMIC EFFICIENCY OF ENGINES AND TURBINE. Steam 120 lbs. Gauge Vac. 28½ Quality 0.98 and

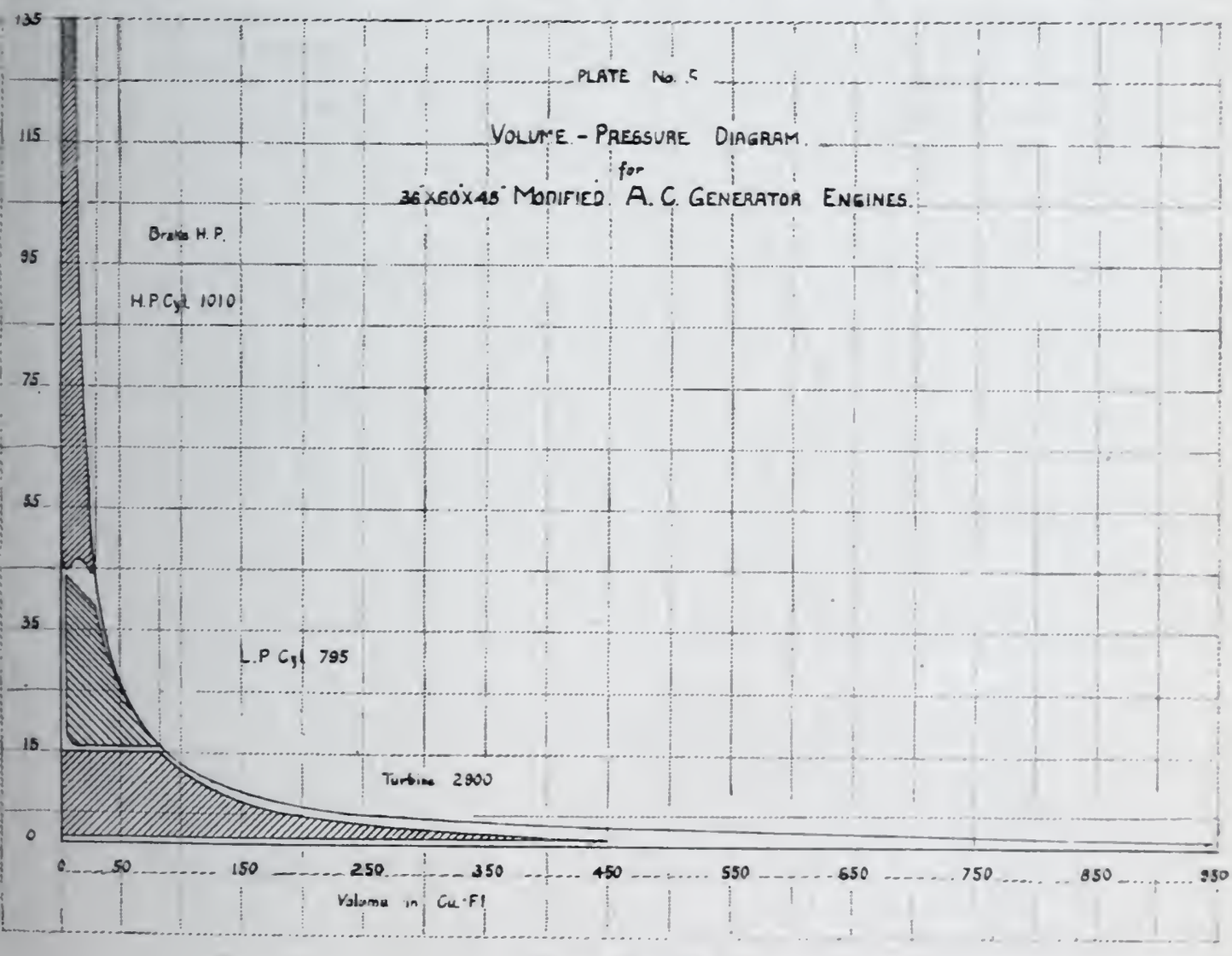

Plate No. 5

hot well temperature of 100 deg. fahr. on the Rankine cycle percent 22.4.

The foregoing is presented in order to show that the application of a low pressure turbine to an existing electric plant does not necessarily require the generation of more steam in order to realize the advantage of the turbine. It may be necessary as in the case thus developed to alter the low pressure cylinders of one or more engines of the system.

In conclusion I would say that I cannot give the Society the detailed results of tests recently completed on the electric plant containing the above engines and a seven thousand kilowat low pressure turbine, but will give the assurance that the estimate of performances of the plant has been more than corroborated owing to the unexpectedly high efficiency of the turbine.

MR. E. D. DREYFUS*: Your attention has already been drawn to the interesting possibilities of the low pressure turbine together with statements of economies which have been obtained through their installation by previous speakers this evening. No doubt a further analysis of what has already been accomplished in low pressure turbine work will be of added interest to the discussion. There have been upwards of 100 turbines of this type sold by the various builders up to the present time. The company with which I am connected has received orders for over 50 of these machines and the following classification shows the nature of the distribution among the various industries, emphasizes two facts. (1st) Those branches which have been among the first to take advantage of the value of the low pressure turbine, and (2nd) those which have had most need of this type of prime mover.

Iron & Steel Mills	8
Electric Railways	9
Machine Shops	7
Cotton Mills	5
Chemical & Electrolytic Works	4
Lighting Companies	3
Lumber Mills	2
Paper Mill	1
Mining Industry	1

*Commercial Engineer, Westinghouse Machine Co., Pittsburgh, Pa.

This includes independent plants only, and not duplicate machines in any one plant.

As the variety of conditions found in steam plants is so great, the low pressure turbine and its auxiliaries must be sufficiently flexible in order to fulfill the requirements in the most desirable manner. Reviewing the installations previously referred, these installations may be divided into the following classes:

(A) L. P. Turbines without Governors. (8).

Generators interlocked electrically with the generators of the main units. High and low pressure machines practically divide load. Intermediate pressure fluctuating, avoiding looping and valve pounding on high ratio condensing engines, and also producing the highest over all economy.

(B) Governor with live auxiliary Steam Admission Valve. (39).

Miscellaneous plants, occasioned principally by different character of load of the main units and low pressure turbines, together with the possibility of deficient exhaust steam at irregular periods.

(C) Governor operated By Pass Valve. (4).

Different load characteristics of main engines and low pressure turbine, with turbine frequently utilizing but part of the exhaust. Engines benefit by partial vacuum when turbine operates on light load.

(D) Electrically connected with the high pressure power through synchronous motors. (6).

Shaft drive occurring in cases like cotton and paper mills having old belted engines installed.

(E) Intermittent supply necessitating regenerator. Reversing and hoisting engine. (4).

(F) Low Pressure Turbine power through Rotary Converters.

Alternating current generation in large units and direct current application in the works through rotary converters, may employ mixed D. C. and A. C. power. (3).

(G) Large Direct Current Machines, with Reduction Gear.

Only direct current desired from power developed in low pressure turbine. In the smaller sizes direct connected D. C. generators are suitable. (2).

This broadly covers the numerous phases which has been experienced by one of the turbine builders which will be found unusually extensive considering this low pressure machine is comparatively still in a state of infancy, having only taken a strong hold in power developments within so short a period of about a year and one-half. The only important exception to the lists just given, appears in the form of a strictly mixed flow turbine. This is undoubtedly an interesting type of the low pressure machine. Apparently, it seems this mixed pressure turbine will fail to reap full advantage of operating with variable turbine admission pressure with any satisfactory degree of regulation. Mr. Stott, at his Interboro Station obtained an improvement of four to five percent over a wide range of load by operating with variable nozzle pressure. He also brought out very strikingly the mechanical advantages in the avoidance of looping, or over compression, with attendant objectionable slamming and pounding of the valves which are well illustrated in the paper read before the American Society Mechanical Engineers, March 8th, 1910. These facts argue very strongly for the use of a low pressure turbine without a governor. Relative to a mixed pressure turbine, a great deal more might be said, but for those especially interested, reference might be made to a recent article in Power, by Mr. Battu, in the May 10th, 1910 issue. It might be added, however, in the investigation of many low pressure problems, it has been our experience that where live steam was demanded sufficiently to cause the consideration of a mixed flow turbine, it might be that an independent complete expansion and a low pressure turbine would be the most profitable commercially and also the most satisfactory.

Some engineers and builders have been prone to deprecate the use of variable pressure operation, stating as the principal objection, the inability to maintain a high vacuum when the

intermediate pressure fell below atmosphere. In well arranged plants this is manifestly uncalled for, as with high grade piping and proper rod and valve packing in the engines, the condensing system is particularly free from air leakage. Mr. Stott has thoroughly proven this in his New York installation. In addition there has been direct evidence from several of our plants on this score, the juxtaposition of the machines not being quite so favorable as where the low pressure turbine is placed immediately adjacent to the engine.

Recording pressure and vacuum charts have been obtained from the Bernon Mills (Georgiaville) installation showing a condenser performance of nearly 29 in. with the turbine inlet pressure only 15 in. vac. or about 8 lb. absolute. At St. Mary's, Ohio, in a railway plant, the initial turbine pressure very frequently reduces to 10 in. vac. without affecting the vacuum. In the latter case, two cross compound engines are tied in with the turbine, obviously involving the necessary stretch of piping between them. This particular station has shown a reduction of 20 percent in fuel consumption over previous practice of running compound condensing engines, and more important, these results are obtained on a widely fluctuating load incident to interurban railway service.

As observed in the classification given heretofore, most of the installations have employed governors with auxiliary valves which may be ascribed to the fact that the conditions of these plants which were first to avail of the low pressure turbine advantages, are not well arranged and more or less improvised methods of operation are consequently necessary.

The most desirable method of installing the low pressure turbine is to operate it as a low pressure cylinder of a compound engine, or possibly of two engines, such as the Interboro plant typifies. Evidently this may only be followed out in the highest types of reciprocating engine plants. Again, as these condensing plants have regularly been developing comparatively good economies, there is not the same urgency for the adoption of the low pressure turbine. Hence the present records do not include as prominent a proportion of machines without governors as will be seen in the near future.

In the other extreme, installations are being made where the engines supplying the turbine are widely distributed. A very interesting example is to be found at the Lebanon, Pa. plant of the American Iron and Steel Mfg. Co., where they have a tributary exhause system fed by 13 engines of different types, and aggregating about 2500 linear feet of piping.

The piping, turbine and condenser erected cost $38 500 and at the rate at which energy is being developed with this unit, the cost per k. w. year is about $7.50, or $5.50 per electrical horse power year, including all charges except fuel, naturally as the exhaust steam otherwise was wasted. It is only necessary to compare this cost with other possible rates from water, gas or straight steam plants to realize its significance.

The low pressure turbine in combination with the compound steam engine has attained results not heretofore reached by any reciprocating machinery of which I have any knowledge. For instance Mr. Stott has shown a combined water rate of 13.17 lb. per k. w. hr. reduced to dry saturated steam. With a mechanical efficiency of 96 percent and electrical efficiency at 95 percent, this would be equivalent to 8.98 lb. of steam per indicated h. p. hour. This is more than comparable with the best types of high duty pumping engines.

The thermal efficiency of Mr. Stott's unit was 21.8 percent, considering the boiler and auxiliary heat efficiency to be about 70 percent, an overall thermal efficiency of 15 percent is obtained. Such results are manifestly approaching the possibilities of the producer gas plant, which in its best attire, performs at about 20 percent but from 17 to 18 percent in regular operation. This comparison applies obviously to large turbine plants only.

It should not be construed that new stations will probably be planned to use such a combined unit, although it is certainly excellent for improving the efficiency and investment value of an existing reciprocating plant. Where coal is sufficiently high to warrant securing the highest possible thermal efficiencies, no doubt the gas plant will be in order. While drawing this comparison between the steam and gas plant, it

might be remarked that the low pressure turbine may be employed in the gas power station to further increase its inherent economy by utilizing the waste heat in a low pressure machine. This is entirely feasible and the efficiency may be bettered from 10 to 20 percent.

It is often humorously stated that the low pressure turbine is an auxiliary to the condenser as it obviously could not exist without it. Some remarks on the condenser should not be out of question. Invariably the low pressure turbine must be considered an improvised arrangement for improved plant economies, and more than likely greater capacity as well. It must therefore, occupy a minimum floor space, together with its auxiliaries in order that it may be placed in the existing plant without any great inconvenience. Fortunately condensers are now available which may be neatly tucked away under the turbines are already appreciated.

As already pointed out, the ensuing practice in low pressure work will not necessarily be guided by the preceding installations.

There is no doubt cooling towers will be employed more extensively in the future. I am personally acquainted with four such plants, two erected and two building. Evidently the vacua which may be secured will only range from 26 in. to 27 in. as an average.

Such conditions call for turbines fully capable of sustaining high efficiencies on these low vacua and it is noteworthy, the reaction turbine particularly suffers small decline in efficiency with reduced vacua.

A previous reference to the low pressure turbine industry being still quite young, applies only to its activities in a commercial sense. Historically, the low pressure turbine was introduced in the later part of the eighties. In 1894 a Parson's low pressure turbine was installed on a British torpedo boat. In about 1900 the Westinghouse Machine Company built the larger turbine of a compound design, consisting of separate high and low pressure turbines, the low pressure having char-

acters identical with the present independent low pressure machine.

Referring especially to pages 375 and 376 of the author's paper, I hardly think the example taken is representative. The engine economics are not as good as we ordinarily encounter in Corliss engine practice. While a great saving may be shown by the use of the low pressure turbine, I do not believe it necessary to take poor engine results to do so, as is sometimes done.

MR. FRANCIS HODGKINSON:* I am not in entire accord with Mr. Gasche in his remarks concerning mixed pressure turbines, and am at a loss to understand his antipathy to the straight low pressure turbine. Doubtlessly, the mixed pressure turbine has its place, perhaps in rolling mills, or some other location where they must needs operate with high pressure steam for quite long periods.

Low pressure turbines are, however, just as applicable in electrical power plants, as in steel mills and the like, as we have heard tonight, in connection with Mr. Stott's plant in New York. Here, in my opinion, the ideal low pressure turbine is a straight low pressure machine without any governor, added to the reciprocating engine just as an additional cylinder would be added, except that it would be connected electrically instead of through the crank shaft and connecting rod. Preferably, the low pressure turbine would have a variable admission pressure corresponding to the load, thus eliminating the looping of the cards at times of light load, which would be the case if the admission to the turbine were maintained at atmospheric pressure, or thereabouts. Such a turbine as this is an exceedingly simple piece of apparatus, consisting merely of rotor and stator, with few turbine elements as compared with high pressure condensing units, and where such a simple piece of apparatus as this, so entirely meets the requirements, why should one complicate the turbine by additional high pressure elements, governor, governor valves, etc., which at best add materially to the complication.

*Engineer in Charge, Steam Turbine Department, Westinghouse Machine Co., Pittsburgh, Pa.

Mr. W. B. Flanders*: I would like to call attention to one point which has just been brought up by a previous speaker, viz., the fact that regenerators did not seem to be required in the installation of the Phillips Sheet & Tin Plate Co. While the low pressure steam supply was subject to interruption of more or less lengthy duration, the supply of high pressure steam would always be maintained at such a point that if not used in the low pressure turbine, it would blow off from the boilers to the atmosphere.

It will be found that this is very frequently the case where rolling mill engines, or those in similar service, are supplying steam to a low pressure turbine. In one case that was investigated, it was stated that about 30 percent of the time, the rolling mill engines would shut down, and therefore, a high efficiency mixed pressure turbine was an absolute necessity.

However, on further investigation, it developed that the greater part of this idle time, the boilers were kept blowing-off, producing approximately the normal amount of steam required for the load on the rolling mill engines. The object of keeping the boilers in this state was so as to be able to start at a moment's notice, or without notice. It was practically never known just how long these engines would be out of service, each time they were stopped, although this idle period might extend over one or more hours.

It then became evident that the economy of the low pressure turbine, when running on high pressure steam, made an absolutely negligible difference in the coal consumption, and it appears this is the case in the majority of the rolling mills. Therefore, is it not better to install the simplest piece of apparatus, viz., a straight low pressure turbine, provided of course, with a valve controlled by the governor, which will automatically admit high pressure steam direct from the boiler? Thus, the complication of additional turbine elements, and of considerable extra valve gear, would be avoided.

In this connection, it must be borne in mind that particularly in the class of service above referred to, reliability and con-

*Engineer, Steam Turbine Department, Westinghouse Machine Co., Pittsburgh, Pa.

tinuity of operation are of prime importance, while economy is a secondary consideration. Therefore, the more simple such apparatus, the stronger the assurance of such continuity.

It might be added that the economy of a simple low pressure turbine, when operating on high pressure steam, is from 6 to 10 percent better than when operating on low pressure steam, and is as good as, if not better than a compound non-condensing engine of similar capacity, running with a steady load.

PROF. C. L. W. TRINKS*: As one of the speakers mentioned a while ago, there existed a low pressure steam turbine craze about two years ago. If you had any power plant trouble, all you had to do was to swallow an exhaust steam turbine and you would be well and healthy as ever thereafter. I can give you another example. Take our own little power plant at the Carnegie Technical Schools where we do not generate enough power to supply exhaust heat to the buildings. We have to turn live steam into the system most of the time, and yet one of the most prominent builders of turbines suggested an exhaust steam turbine as the unfailing remedy for our rather high fuel consumption.

Still the low pressure turbine has done some good. It has completely changed the aspect of the engine market. About three or four years ago it looked as if all builders of steam engines would have to quit business. Nobody wanted any more engines; all power plants were "going turbine," and rolling mills were all to be driven by motors, the electricity to be generated by blast furnace gas engines. The outlook was sad, when the low pressure turbine appeared as the saviour of the steam engine industry. Now we build steam engines just as we used to do and exhaust the waste steam into turbines which make juice.

But the turbine is not limited to the generation of electricity, it does just as well on the generation of blast for furnaces by driving turbo blowers; and right here I wish to make a prediction: The development and use of the turbo-blower

*Professor Mechanical Engineering, Carnegie Technical Schools, Pittsburgh, Pa.

will be just as rapid as that of the low pressure turbine and in a few years they will be built in large quantities. I do not mean the blower of the "inverted Parsons" type, because I do not think that it will ever amount to much—this is a private opinion, which a professor has the right to have and tell his students —but it will be the blower of the Rateau type. And say, my hat is off, when you mention Rateau. Anybody who can get royalty on a plain tank half full of water and half full of steam, certainly knows his business.

MATERIAL ECONOMICS

By T. D. Lynch*

We have given to us in nature certain elements which separately or in combination make up the material universe as we know it. These elements may be formed into materials of a variety sufficient to meet every commercial requirement.

Few engineers and fewer laymen realize the great complications and possibilities in the make up of these materials, neither do they realize what it means to deviate even slightly from the beaten paths of regular manufacture, although it be to meet only a slight change in performance.

This may perhaps be best understood by way of illustration. A solder was wanted having a high melting point, higher than that of pure tin. The melting point of tin is 232 deg. cent. The melting point of lead is 331 deg. cent., therefore, it was decided that 50 parts of tin and 50 parts of lead smelted together would give a happy medium just half way between that of the melting point of tin and lead, or 280½ deg. cent., but not so, on the contrary this combination of tin and lead produced a solder that melted at 198 deg. cent., very much less than the melting point of either tin or lead.

Again there was an urgent demand for a collector ring having one-half the electric conductivity of copper and with this the natural suggestion that sometimes goes with the demand for such material was forthcoming, namely, to add lead, tin, iron, or other low conductivity metal to copper in the proportion of the relative conductivities of the different elements in the alloy and thereby obtain the desired conductivity of the mixture, but unfortunately copper alloys do not work out that way. A red brass containing 87 percent. of copper has a conductivity of only 18.2 percent of that of pure copper, thus we might enum-

*Research Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

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erate only to show that elements do not always give mathematical results when combined one with the other, but must be studied experimentally and scientifically before the true results are known.

On the other hand the possible combinations and variations of the elements are appalling. These variations may be due to the proportional parts or changes in the elements, and to illustrate the possibilities of certain of these elements we cannot do better than to choose that of carbon. Pure carbon in the form of graphite is one of the softest materials in commercial use. Pure carbon in the form of the diamond is the hardest of materials in commercial use, these two differing from each other only in the formation of the atoms in the molecule.

Carbon exists as coal, furnishing the fuel supply which has made Pittsburgh and other coal centers famous. Carbon forms a large part in the make-up of all vegetable and animal life and it is about us on every hand.

The manufacturer of steel finds in carbon that element which transforms iron into steel, and, by slight variations in the carbon content, may produce steel of widely different qualities, such as a rivet steel carrying 0.10 to 0.12 percent of carbon giving a ductile product of approximately 50 000 lb. per sq. in. tensile strength; axle steel carrying 0.35 to 0.50 percent of carbon gives a less ductile but stronger material of approximately 80 000 lb. per sq. in. tensile strength; spring steel carrying 0.90 to 1.10 percent of carbon gives a product that may readily be annealed so that it may be machined, or tempered in oil or water so as to give the proper resilience suitable for a spring. This same quality of steel carrying approximately one percent carbon when drawn into a wire will give a tensile strength of 300 000 to 400 000 lb. per sq. in., so that in steel we may get 50 000, or 400 000 lb. per sq. in. depending primarily upon the carbon content of the steel, and secondarily upon the work given to it.

Carbon plays an essential part in the manufacture of malleable iron, which when cast is white in color and as brittle as glass, the carbon being in the combined state. Malleableiz-

ing, or the process of making white iron malleable, consists in changing the carbon into the graphitic state (formerly improperly known as de-carbonizing) and when this is properly done, the iron is made soft, or malleable and the color is changed to a dark gray.

As it is with carbon so is it with many another of these elements; their influence in combination with other elements is excedingly important and far reaching.

Engineers, chemists and financiers have labored together and have succeeded in forming combinations of elements under specific conditions to serve a definite purpose, and form an integral part of a manufactured whole. These attainments have not been reached quickly nor easily but by successive steps, counting among them many, many failures until now we have at our command a great mass of data, much of it carefully compiled for ready use, yet there lies before each of us incessant labor if we but learn how to apply this information to make it most useful in providing material that is good enough to meet our several needs as students and as men of action.

The modern engineer looking to the greatest possible economy recognizes the fact that "Good Enough is Best," but in making this statement we would emphasize the further fact that any material which gives trouble is not economical nor good enough for that service.

The study of materials and the problem of making appropriate application of them suggest four general classifications, viz., Research, Design, Manufacture, and Cost.

Research: Research consists not only in the study of materials as such but also in a study of their proper application in construction. There is a tendency, however, on the part of many engineers and especially those of limited experience to minimize the importance of the proper use of materials in design.

Too often designs are completed with only a limited amount of information essential to the selection of proper materials that may be available, instead of first carefully studying the subject and determining just what qualities are necessary and what requirements are to be met. It is not unusual for material

to be ordered by designating simply the broad term by which material is known, e. g., lubricating oil, paint, babbitt metal, steel, wood, or coal, leaving the modifying qualities, kind or grade an open question. This plan invites and seldom fails to produce trouble in some form.

Research work and the marked improvements to be had through the careful study of materials and the proper application of them has come to be recognized as a necessity, and the general question covering the systematic study of all materials in connection with design and methods of manufacture gives not only greater economy but also a better final product than would otherwise be obtained.

Happily there are many materials in common use which have their qualities well established and their several grades best suited for a given service are well defined; this renders it a simple problem to select and order such material for a definite purpose and get that which is wanted.

A very common method of doing this is to order material by specifications that are standard to the trade; e. g. when a steel is required of 0.35 to 0.50 percent of carbon, under 0.05 percent of either phosphorus or sulphur, and having a tensile strength of 75 000 to 90 000 lb. per sq. in., together with good ductility, order "Axle Steel" specifying the essential characteristics that are standard.

When a structural or building cement of high grade is required, order "Portland Cement" as per standard specifications of the American Society of Civil Engineers or the American Society for Testing Materials, such as have been so well standardized by these societies.

So it is with a great many of our materials, but there are also many materials of which very little is known as to their characteristics and proper application. These unknown materials are more problematical and require a systematic study before they too may become standards.

A single test will usually determine to which grade a material belongs when the grades of that material are once established and the requirements specified, although we cannot

emphasize too fully that no one test of a given sample is sufficient to establish a grade from which to order that material.

It is sometimes necessary to select a new material on the basis of a sample, and whenever this is necessary the following plan has been found to be quite satisfactory, viz. A small sample is tested in the laboratory to verify the claims made by the manufacturer or to try for commercial use a material which it is thought will meet certain requirements. If the indications of the laboratory test are good, a shop trial is made in regular commercial work, and, if this test shows the material to be suitable, a trial order is placed, used, and carefully examined while being used under normal shop conditions.

Too much emphasis cannot be placed on the importance of a series of tests as outlined rather than a test from one sample. Samples are not always representative; often indeed are they selected and anything but representative, therefore the plan of first a laboratory sample, then a shop sample and finally a shop trial order has already demonstrated the wisdom of its adoption.

A trial order for any new material should include a sufficient quantity to get at the real merits of the material under the conditions for which it is intended to be used.

May it also be born in mind that there is a marked difference between testing an ordinary commercial material for which its manufacturer seeks to find a market and in furthering an investigation to find a material which will meet some unusual or exacting requirement, or perhaps to determine which one of several materials will best meet a given condition to be fulfilled. If the investigation is to test a manufacturer's material and find a use for it, the first disapproval of the sample submitted may result in final rejection. On the other hand when a material is found which appears to fill a real want that has not already been satisfactorily met, the manufacturer should be encouraged by giving him full results of tests and point out the good qualities and wherein the material may be improved, including possible suggestions that may be of assistance in meeting the requirements fully. Further samples are then care-

fully tested and reported as above until a suitable laboratory test is found, after which the shop test and trial order must also be found satisfactory before the research may be considered complete.

Materials thus tested have been found to give sufficient data to check future shipments with a fair degree of accuracy, and are usually satisfactory for the one grade of material tested and from that particular manufacturer. However, similar tests need to be made on different grades of material from the same manufacturer or on the same (so called) grade from different manufacturers. The facts obtained from the results of tests on subsequent shipments, may soon be and usually are sufficient to formulate into written conclusions and to put into a purchasing or contract specification. This specification may serve not only a good purpose for the immediate present but become a permanent factor in the commercial world.

Every new purchasing specification put into effect should establish a standard for the material represented by it, and should place clearly before the manufacturer those points which can and must be met by him and at the same time protect the purchaser in that he may expect a definite thing for which he has need.

A progressive manufacturer who is honest almost invariably welcomes a carefully worked out and a well drawn purchasing specification, because it protects him against the unreliable competitor.

The fundamental principle in connection with the preparation of a purchasing specification should be to specify *performance* and not construction or composition. It should include only that which is needed, should be brief, clear and positive but not too rigid, and to be complete it must cover all essentials. It is not always possible, however, to make a purchasing specification complete at first writing, the performance may not have been fully determined or a satisfactory test other than that of actual service may not be possible, or again a certain composition and method of manufacture may be known to give a definite performance; in which case it is well to speci-

fy the known features whether composition, method of manufacture, general construction of the material, or perhaps partial performance, and, as a further assurance of good faith, secure a guarantee from the manufacturers that the performance of the material to be furnished will be at least equal to the sample tested, and as a penalty impress the fact upon the mind of the party furnishing such material that orders will be continued only on the basis of his furnishing a uniform material as per samples tested.

It naturally follows that our best and most effective purchasing specifications are developed by making use of all known information, keeping close record of working data on the various shipments as they are being worked up and eventually formulating this into complete and final form, which requires constant vigilance and research.

One of the most difficult problems in connection with research engineering is to get a man properly trained and indeed made of the proper material himself to do his work efficiently. Mr. C. E. Skinner of the Westinghouse Company in an address before the Engineering Assembly of Purdue University in January, 1908, and published in the Electric Journal of April, 1908 has ventured a specification for a research engineer, and I cannot do better than to quote: "The man who is engaged in research work should have a thorough technical training; he should be capable of close observation, should be able to think straight, to draw logical conclusions from experiments performed. He should not discard results because they do not prove preconceived opinions; he should be able to get all the data required or available; he should be able to distinguish the important from the unimportant and not be misled by some minor or interesting ramification of the subject. While he should be capable of framing theories, he should not insist that every test proves his pet theory. He should be judicial; he should be capable of considering the opinions of others; he should not try to account for effects by some abstruse theory when the cause is very simple. He should be capable of working with others in his organization without friction, he should

'play the game according to the rules'. He should be in every sense of the term a true gentleman.''

Design: A second member in this family of material economics is that of design, which links itself very intimately with the problems of research. The design of any finished article or equipment should be given very careful consideration so that it will fill the need for which it is intended to the best possible advantage.

The steps in any new design should be to study it as it really exists, examine the subject as a whole, procure the real facts in the case and in so doing make use of theory and standard works, consult current literature and advise with men of experience, but, above all else, in this investigation get facts and not opinions. Too often opinions are formed without all of the facts, and one may readily see how fallacious hastily drawn conclusions may be. Facts, once having been obtained may be formulated into judgment, which judgment will stand the strictest scrutiny because founded on facts.

In this study one should get a general view of what he is about to manufacture, outline the various steps in their proper sequence, look into the details of each operation, with special reference to methods of manufacture in use and tools available for the work in question, or what tools may have to be purchased for economical manufacturing, and last but not least, determine the grade and kind of material to be incorporated.

It is fundamental that this information must come from the closest co-operation of every interested department; the Sales Department to obtain the definite information and conditions that are to be met; the Engineering Department to determine what materials are necessary and what electrical and mechanical requirements will be needed; the Laboratories to advise what materials are commercial and their physical, chemical and electrical qualities; the Manufacturing Department to determine the relative cost of machining and fabricating the different materials into a finished apparatus, and thus be enabled to determine just what is wanted.

In designing it is of prime importance to be able to use material that is commercial, such as can be had in the open market and if possible from stock. Such material is always cheaper and usually better than anything that is special. To illustrate: A few years ago the steel manufacturers were called upon to roll an increasing number of cross sections with varying weights per foot of "rounds" and "steel shapes," such as angles, channels, I-Beams, Z-bars, T-bars, etc. Any slight variation in width of flange, thickness of web or flange or diameter of bar that seemed desirable in a new design, was ordered, regardless of any standard, until the vast number of variations in both shape and sizes were legion, gradually increasing the cost of making and maintaining such a variety of rolls necessary to produce this variety of shapes and sizes until it became excessive, or we may say prohibitive. This led to the formation of the Association of Steel Manufacturers, which, after due deliberation, adopted certain average standard sizes and cross sections of shapes and rounds, making their prices on these standard sections with an extra charge for any deviation from them. It is needless to say that only a short time elapsed before the designing engineer found he could use the standard shapes and sizes and take advantage of the reduced price. Today the prices of steel shapes and rounds are quoted on base sizes, with a fixed increase of price for any deviation from these base or standard sizes.

Anything special requires additional labor to produce, and any material or manufactured article that is even slightly different from that regularly manufactured is special and must necessarily entail extra cost. Therefore in economical design a very thorough knowledge of commercial materials is not only desirable but essential. This knowledge may be obtained by long continued experience, or, as is customary in large concerns, by preparing and carefully arranging standard sheets, keeping them up to date and in shape for common reference. These standard sheets should cover sizes, shapes, characteristics, grade, and any special features of standard materials commonly used; also a list of special approved materials for which

there may be special demand, giving relative costs of the various grades.

In the manufacture of electric equipment this includes all kinds of fabrics such as cotton, linen and silk insulation; all kinds of metals such as copper, steel, iron, brass, bronze, tin, lead, aluminum, babbitt, solder, etc.; cements, impregnating compounds, oils, paints, varnishes, lumber, coal, rubber, porcelain, glass, etc., all of which simply go to show how much there is to take into account in design and how necessary it is to keep strictly up to date on the best material for a given purpose, bearing also in mind that the cheapest material is not always the most economical. A better grade may go enough further or in some other way prove to be more economical than the cheaper goods; on the other hand a cheaper article may be much better than the more expensive one if properly applied. However, one should bear in mind, as stated before, that "Good enough is best."

A few examples of what it means to select material for a given purpose may be of interest. Copper drawn as hard as possible is required for commutator bars, connectors, cross bars, line wire, etc., where strength, rigidity, and wear are essential, while soft annealed copper is of equal importance for magnet wire, which must be soft so that it may be bent, pushed or hammered into the various irregular shapes into which it must be formed.

Another example is that of armature banding. Only a few years ago it was common practice to band armatures with phosphor bronze wire, but today the high speeds and correspondingly high centrifugal stresses have necessitated its being replaced by tinned steel wire, which has much greater strength and is cheaper.

Again, the early machinist oiled his drill press, mill and planer with sperm oil, lard oil, or other animal oil, while today mineral oil is used almost exclusively for this purpose, being much cheaper and in most cases better.

Supply and demand determine our prices, which are continually changing, often leaving to our judgment the choice

of what materials one should use. For example, the past decade has made some marvelous changes in the manufacture of steel castings, the United States Navy probably leading in this development by enforcing the improvements that have been made. However, they have not been alone. About 10 years ago a demand was created for heavy steel discs, varying in size from 24 to 80 inches in diameter, and weighing from 3 000 to 50 000 lb. each. Some of our leading engineers and managers were agreed that such discs could be made only as forgings. There were then but two manufacturers in the United States who could handle forgings of such dimensions, and so the price was high, there being little competition. A few discs were forged, tested, and the smaller ones accepted and put into service; these smaller sizes were quite successful, but the larger sizes a failure, the failure of the larger sizes being due to the fact that even our very largest modern hammers available for such forgings do not work material thoroughly when in such large mass, and besides, while ductility may be increased axially by the forging operation, it is lessened in the radial direction.

Forgings are also subject to longitudinal cracks, white streaks, and hard spots which are not explainable in a satisfactory manner, even by steel manufacturers, and this adds to one's hesitancy in the use of very large forgings in the form of discs that are subject to high centrifugal stresses. These difficulties and uncertainties led to investigations that were carefully made regarding the possibility of making these discs in the form of steel castings, the idea in general being anything but a popular one.

An order was placed consecutively with several of the most prominent steel companies who were making steel castings, each proving a failure but each adding its part of accumulated information to the records that were carefully kept, until finally one manufacturer was prevailed upon to co-operate in making a comprehensive study of the subject, including the whole problem of the mix of the steel used, the temperature of the steel in the melting furnace, pouring temperatures, amount

of riser, shape of casting mold, thickness of sand in the mold (governing the rate of initial cooling), the annealing time and temperature, special tests, etc. The final results were a very superior quality of casting, quite uniform mass, solid throughout, approximately equal strength in both radial and axial directions, a commercial product, and moreover, at a cost of only one-half or one-third that of the original price of the forging. This development produced a new competitor, and the forging companies were forced to a normal price, which was even less than that of the casting company's price for the castings, resulting in returning to forgings for all small sizes suitable for forging, and giving a source of supply for the larger sizes that could not be forged. Here design, research and manufacture worked hand in hand.

The working out of this problem was not one-sided, but was accomplished by team work. Each specialist did his part, the designer, manager, metallurgist, melter, molder, and finally the engineer who was responsible for the problem as a whole. It was up to the engineer to make use of the data obtained from these various specialists, and it is this class of work which is truly commercial research work as applied to design, and when properly executed gives us a material, better adapted to the use for which it is intended, and finds for the different methods of manufacture their proper place in the production of apparatus.

Manufacture: Our third division brings us to that of manufacture. Too much cannot be said about simplicity of manufacturing processes and standardization of work, and under the caption of manufacture may be included the manufacture of the raw material, its inspection and tests, and the fabrication of it into finished apparatus.

Under the manufacture of the raw material it is of prime importance to select a material that is of regular manufacture, such as can be obtained in open competition.

There should be thorough inspection and tests to verify the quality and workmanship of every shipment of raw material

in order to make sure that the material is up to the grade purchased.

Material can be kept up to grade only by proper inspection and this inspection should be done before the material is approved for stock, and any that is found not to be of proper quality should be returned immediately to its manufacturer. The manufacturer should be furnished with such information as may enable him to locate the individual whose carelessness may have caused the defects or the one who permitted the inferior material to be forwarded.

One case of trouble run down to the cause of the trouble and to the individual who caused it is worth a thousand general complaints.

It is human to shift responsibility for mistakes and any general claim leaves room for discussion, but when the facts in any definite case of trouble are clearly set forth, every one concerned will invariably do his best to correct that trouble and prevent its recurrence.

To illustrate: A small porcelain piece used in a lightning arrester was purchased in large numbers which, in the assembling was found to be defective on account of certain holes being too small and 16 000 pieces were rejected and the manufacturer notified in writing. A later shipment showed the same trouble and further rejections. The porcelain manufacturer became incensed at the second rejection and wrote a letter to the effect that he could not stand for any such rejection and demanded that all orders for that piece be cancelled. A trip of inspection was made to the plant of the porcelain manufacturer, a plain talk was had with the manager and the subject fully set before him. The error causing the trouble was located, all standing orders were promptly filled, and future shipments were properly made. As usual, a very trivial thing had caused a large amount of discussion and a clear understanding corrected it. Facts and horse sense remove mountains of trouble but nothing short of this will do it. In the fabrication of material into finished apparatus it is of even greater importance than in the case of raw material to have all special features eliminated

and to simplify every operation, since a regular manufacturing operation is both cheaper and better than where there are special features. Men become experts, in making an article in a definite way, of uniform component parts, and with suitable equipment; but any changes, however slight, court trouble.

It is surprising how lightly these points are looked upon by a large percentage of manufacturing superintendents and it is no uncommon occurrence to be able to cut the cost in half by simplifying the material and manufacture from special to a regular commercial proposition, thus leading to standardization and standards.

However, there are often special features that must be met. In such cases let them be as few as possible, and even in this, one should use regular material and methods and adapt them to special purposes in order to reduce all special features to a minimum.

To illustrate: A request for price and delivery was made of a manufacturer for 16 large clamp rings each weighing about 5000 lb., too large to be rolled in a tire mill, yet they must be weldless and uniform throughout. The manufacturer proposed to forge a large flat plate and cut one ring out of each plate, and made a price of 28¢ per lb. or a total of $22 400. This price seemed to be too high, but the rings were special in size and shape and must be had.

It was commercial, however, to have a plate rolled instead of forged to the proper thickness, and a boring mill of the proper size to cut the rings from the plate was available; and so the commercial plates were rolled, the commercial mill was used to cut out the rings, and a commercial price of $9400 was paid instead of the non-commercial price of $22 400. This represented a saving of 58 percent or $13 000 on one item by the simple rule of using that which is commercial in the different operations of manufacture, although in the end producing a special thing. So it is in every feature of manufacture, that which is commercial is best.

Cost: Our fourth and last sub-division brings us to that of cost, which enters into every commercial transaction and every manufacturing operation.

The manufacture of elements into commercial materials and the fabrication of these materials into a finished, useful product requires labor, and so we have two main items entering into the cost of manufacturing any piece of apparatus, viz. material and labor. The cost department of a large concern would have you believe that there is a third item—overhead charges, covering interest on the investment, expenses of maintenance, depreciation of plant and general supervision that cannot be charged directly to the several orders as they are being manufactured; but when overhead charges are analyzed, only material and labor are found to be included.

The true cost of an article therefore is material plus labor. Material without labor has but little value. Iron ore as it is found in the hills of Michigan may serve as a good example of material in its crude state, to which labor is added and wealth is produced. A study of the ore is inaugurated, analyses are made, a company is formed, the ore is mined, loaded into cars, hauled to the lake, dumped into a vessel, shipped across the lake, transferred from ship to car, hauled to the blast furnace, dumped into an ore bin, loaded into a small car, transferred to and (together with alternating layers of coke and limestone) dumped into a blast furnace, the blast is turned on, the ore is refined and drawn off as molten iron into pigs or what is known to the trade as "pig iron." These in turn are remelted in the open-hearth furnace or Bessemer converter, refined into steel, poured into ingots, rolled into blooms, slabs, or billets, reheated and finally rolled into finished plates or shapes to be fabricated into a bridge, or perhaps into the steel frame of a large building.

It follows therefore, that iron ore, limestone and coal, plus labor, produce the steel structures that span our rivers and make possible the great engineering feats of this, the Iron Age. And so we have these two items, material and labor, entering into the cost of production. Each labor operation has added cost, and all unnecessary labor or waste of material has added additional cost, hence the importance of economy in the various operations. Economy means success; carelessness and waste mean ultimate failure.

The labor problem is a very large one and one special to itself, so that the intent of this paper has been to take up only that phase of labor involved in providing a finished product that is good enough to serve well its purpose and at the same time be able to produce it at such a cost that for every dollar spent there will be more than a dollar in return.

This means that costs must be known at the earliest possible moment, and it is our good fortune to live in this age when engineering has become such an exact science that, in most cases, cost may and should be counted before manufacturing operations are begun, and if the profit and loss balance is on the wrong side, the trusted engineer must determine this, say so, and stick to it. Learn to say no. Sufficient time should be given to insure proper investigation and accurate reports. Hastily prepared reports have gotten many an engineer into trouble. If a man is called upon to make a report in a shorter time than is possible by known methods, he should say so and stick to it; learn to say no. To illustrate: A chemist was given a material to analyze and was limited to three hours for his report, while in fact it required eight hours to complete the test. A quick estimate was made and report handed in at the end of three hours. The material was used and luckily found to be allright. The eight-hour or true test was also reported in due course. A second shipment was likewise tested and passed, on the three-hour (estimate) test, the eight-hour test report following as before and the material proving O. K. A third shipment was received, the three-hour (estimate) test reported, and the material used, but when the eight-hour (real) test was completed, it showed the material to be defective but too late to prevent the loss of not only the material in question but also that with which it had been intermixed.

Undue haste was solely the cause of this waste and corresponding excess cost. The chemist was called to account for sending in an erroneous report, who in his own defense referred to his eight-hour or real test report, which showed the inferior quality of the material.

It is needless to say that thereafter only the report that

really meant something was accepted. That manager is typical of many managers in asking the impossible of his subordinate, and that chemist is typical of many a chemist or engineer who has not learned to say no. "Guesswork made respectable by antiquity" is no longer an acceptable excuse for excessive cost, so that defective material, unnecessary repairs or inefficient equipment means failure to those who are thus relegated.

In the selection of material one's investigation should be thorough, the application appropriate to the design, and the methods of manufacture commercial and economical, while the aim should ever be to reduce the cost of production without decreasing the efficiency of the apparatus or to increase the efficiency of the apparatus without increasing the cost of production.

DISCUSSION

MR. J. H. BAKER: I am sure the author of the paper will agree with me, that we come to very many places in very many things where we never know, and we are trying to find out. And I am sure any man that has followed as closely as Mr. Lynch and many more of you the questions involved in materials, will agree with me that the choice of materials and the understanding and knowing what is best to do after selection is something we never will know all about. There are some materials I have been working on for a long time, and I want to tell you tonight I feel very much like a little boy about most of them. The farther we go the more we find there is to be looked into, and you will pardon the paradox, the more we know the less we know.

MR. R. B. WOODWORTH: I came here this evening to learn and I have learned a good many things from this paper, which I have enjoyed thoroughly. I think it can be said without contradiction that the amount of knowledge which we have today in the use of the materials of construction as distinguished from that which was possessed by our predecessors is due to the faithful research of men who have stood on the facts which they have found and have drawn conclusions from those facts

rather than on the basis of their preconceived opinions. At a banquet of this Society not so very long ago Dr. Brashear informed us that Professor S. P. Langley, who has done so much in the field of scientific research, told him that the solution of every problem which man has solved brings with it four other problems to be solved, so that the bounds of science are constantly extending. I think you will find that is true in the history of the use of materials.

Ten to fifteen or more years ago men used whatever materials were at hand in the best way they could and perhaps with less economy and with less real certainty and accuracy than we use them today, and by reason of that less real certainty were constrained to use larger sections than would perhaps be considered amply safe for the purposes in the light of the knowledge which we now have. The difference between those conditions and the ones that obtain today is due simply to the fact that today is the day of the testing machine, the day of specialized research, the day of knowledge based on that research and of the special uses to which material under scientific investigation can best be put. If we are to increase in knowledge and in the ability wisely to use the resources which nature has placed at our disposal, it will be in so far only as specialists trained in the arts of research add to our knowledge and to our skill.

In the field of steel materials, that is, materials which in a general way are made out of iron in the bessemer converter or the open hearth furnace, or other methods, rather than by puddling, there have come to the front in recent times new alloys, new uses and new conditions to be met, and at the same time, concurrent with discussions as to the conservation of all our resources, there is a disposition towards the use of lighter sections wherever safely possible. Very often the manufacturers of these special grades, or, if you please, kinds of material, are over-sanguine in their expectations of what their materials will accomplish and over-zealous in their recommendations as well. The engineer himself may also form incorrect ideas as to the endurance of the materials which he proposes to use, and in-

stances are not few of disastrous failure caused by erroneous ideas as to the strength of materials.

The best proof of the fitness of a given material for the purposes to which it is put is of course its endurance under conditions of service over long periods of time, but next to that the testing machine is the final arbiter for the reason that it does provide a means of obtaining accurate information as to the probable endurance of the materials tested under conditions similar to those of actual use in a short period of time. The testing machine, therefore, and its results must be the final basis of accurate conclusions, in all engineering work, and on the basis of testing only can we build wisely and well.

The study of materials is thus a subject which calls for trained ability, patience and scrupulous exactness of no small order, and the success of the engineering profession today is due largely to the self-sacrifice and conscientiousness of the men who have been willing to spend their days and nights in patient research. As a rule few engineers have either the ability or the time to devote to this pursuit of science nor often do they have at their disposal the facilities in the way of laboratories and equipment which advanced research necessitates. In consequence a great deal of our testing is carried on in the schools of the profession and a great deal by trained engineers in the service of the large manufacturers, but the problem to be solved is born from the necessities of the practicing engineer himself; and just as the grammars and dictionaries follow the course of a spoken language, as new conditions gave birth to new ideas and new nomenclature, so the schools and the testing laboratories have to follow the practicing engineer and his problems. It is a very healthy sign of present day progress and bodes well for the future that the testing laboratories and the research engineers are in very much closer contact with the men who are actually called upon to do things than the grammar books, dictionaries and schools of languages are with the men who have to use it in correspondence, technical discussions and the ordinary affairs of our highly organized and specialized modern life.

Mr. J. J. Shuman: I was much interested in this paper. Mr. Lyneh has brought out eertain ideas in such a forcible way, ideas that have been more or less in my own mind for some time, that I have been greatly pleased. It just occurred to me as he was giving Mr. Skinner's "speeifieations for the research engineer," that the large steel eompanies wish their customers might all be built in conformity with that speeification. Unfortunately this testing of materials whieh has come upon us so suddenly has earried some of its devotees off their feet, so they do not really understand what they are doing.

Just as an instanee let me eite the present attitude of one of the large automobile manufaeturers, a consumer of forging steel in large quantities. This eoncern has a eorps of engineers who have written speeifications for steel that is to go into eertain parts of their maehine. Now eaeh speeifieation is such a hard and fast affair that the most insignifieant deviation from it is a basis for the rejeetion and return of the material, no allowanee at all being made for the normal fluetuating metalloids. The trouble with these men is that they have no practieal knowledge, no real knowledge of the material with which they are working. He is really going at the matter in a theoretical way and requiring aetualities to meet the theory. I might add that this eonsumer is teaehing the manufaeturers to say "No." Mr. Lynch has mentioned that it is very desirable to be able to say "No." Some people find it difficult to do so, but at times they are foreed to do it.

This judieial mind is really one of the first requirements in an engineer, and it is the one thing needful to promote cooperation in business. The ability to put yourself, at least in a measure, in the other fellow's plaee is a great help to both parties. I speak with some feeling, too, for it has been my lot to investigate and if possible adjust a large number of material claims, and in this business I have had it borne in upon me strongly that if all business men were willing to go at least half way in the adjustment of differenee, business would be greatly simplified.

Mr. H. W. Fisher: I have been very much interested in Mr. Lynch's paper. I have known for some time of the good work that Mr. Lynch has been doing, and I think we, as engineers, realize how little we know of the immense amount of detail belonging to any particular branch of engineering work.

I happen to have in mind some research work which we have been doing with compounds for insulating purposes, where we found a number of those very peculiar things concerning which Mr. Lynch has spoken. For instance, some compounds show a dielectric loss that has a minimum value at a certain temperature. It is natural to conceive that the loss should be greater at increased temperatures, but one would not expect an increase at low temperatures and I would like to ask if anybody present can offer an explanation for this. I have not been able to determine the reason and can only conclude that some unusual molecular change takes place in these compounds when cooled beyond the point of minimum loss.

Then we have other insulations in which the viscosity varies directly as the pressure, and still others in which the viscosity varies as the fourth power of the pressure, so you can have all kind of variations between those two limits. Generally speaking, the compound whose viscosity varies directly as the pressure will saturate fibrous materials well, while the reverse is true of the compound whose viscosity varies as the fourth power of the pressure. So when you come to the manufacture and use of insulating materials such research work is of the highest importance. What I have said is only a fragment of what might be said regarding insulating materials alone. When you consider all the diversified work of a large company like the Westinghouse Elec. & Mfg. Co., one can realize the immense amount of detail and research work that is necessary in all departments.

Mr. R. A. Cummings: The subject has been comprehensively handled by Mr. Lynch, but to my mind the most significant part of the address are the specifications for a research engineer. I am quite sure the majority here will join with me

in testifying how admirably Mr. Lynch fulfills the spirit and letter of these specifications in the broad field of his own investigations.

It is indeed difficult to select one individual phase of this subject for discussion from such a wealth of thought. The very essence of modern engineering is wrapped up in the consistent development of materials and their application to engineering structures. Research is a necessity and involves the testing laboratory. The fund of information obtained from close observation and investigations into the physical or chemical qualities of materials is a "sine qua non" and a great advantage. The designing engineer is dependent upon complete data and his work will reveal the extent of his technical information. For this reason he must be an intellectual leader in his profession. Yet there is another phase of the subject that should be mentioned here for it is one that the speaker recently brought before this Society in an address on "Concrete Construction" It is the inter-dependent relation of efficient design and constructive knowledge. As much as concrete design depends upon a suitable choice of material, equally as much does its proper application depend upon the fullest appreciation of practical methods for construction. With this combination the greatest economy must result. The "blanket" or "Big Stick" clauses of structural specifications covering up the "factor of ignorance" would be eliminated and become a thing of the past. Hence the risks would be reduced to a minimum for all parties interested.

It is a fortunate and healthy sign of the times when we find a large manufacturing firm conducting its affairs upon such an analytical system as indicated by Mr. Lynch. If this were more general and the knowledge obtained were freely disseminated, many troubles and great technical progress would follow. It would be fortunate indeed, if this Society could be made the medium for presenting without prejudice a tithe of the general engineering data collected by such corporations now available only to the individuals identified with them.

MR. S. E. DUFF: I think Mr. Lynch's paper contains so many separate and distinct words of wisdom that it would be impossible to even mention them without taking up as much time as was consumed in reading the paper.

One particular point struck me forcibly. It was his remark that *"good enough is the best."* Follow out that thought and consider something that is a little outside of what we generally think of in engineering, and that is the enormous waste in general lines of business or in the general merchandise business of the world, due to the fact that people do not take into account that *"good enough is the best,"* but are willing to pay all kinds of fancy prices for material which is no better for their purpose than some which could be produced at a lower cost. As an instance, the question of lubricating oil, which I do not claim to know much about, but I do know that a good many people are paying fancy prices for special lubricating oil when a very low priced oil would serve their needs even for machines of several different types if they only knew how to buy it and how to use it.

The great manufacturing organizations of the world have been made great because they standardized their product and brought all their operations to a high state of efficiency and a high state of accuracy. In order to standardize their product they had to standardize their purchases. This is well known to all engineers, but it is interesting to consider the enormous number of quasi-manufacturing concerns which will deliberately buy in the market what is offered to them without following the rule Mr. Lynch lays down, that *"good enough is the best."*

MR. ARNOLD STUCKI: I believe the paper hit the nail right on the head. I have been on both sides of the fence and I believe I appreciate it as much, or more, than anybody else. Once in a while a paper like this will do a whole lot of good to the manufacturer as well as to the engineer. The manufacturer must be encouraged in doing certain things and doing these well, and if we are not constantly at him it is natural that he looks for output and lets it go at that.

One point I want to bring out is that without the research engineer we could not develop our industries as we do. Without proper knowledge and without tests and researches we would not have the steel castings we have today, and we all agree that we can do still better, and that some day we will have material that is far superior commercially to what we have today.

Referring to Mr. Lynch's expression, "good enough is the best," I think it is generally wrong to design a spring of a high grade of special steel, when we have room enough to get in a spring made of commercial steel, which is open hearth. I bring that to your attention because I know some engineers still think we should stick to a high grade steel, which is all well enough in special cars, but ordinarily a commercial material should be used in preference. Again, in order to get an inexpensive article, one which is lasting and one which comes out of the factory uniform, we must apply commercial methods, such as multiple, automatic, and self feeding machines. This way the human element is eliminated as much as possible and the product runs more uniform.

Mr. Edward Godfrey: I would emphasize what Mr. Lynch says about the use of standard materials and standard methods. The steel manufacturers, and also inspection bureaus, understand what confusion there is in small variations in specifications. Steel will be specified 54 000 to 62 000 lb. per sq. in.; another one will want 55 000 to 65 000; another 56 000 to 68 000, and so on, limits that are just a little different. And if the material falls outside of one of these, it may still be inside of another. One purchaser will accept it and another would reject it, when in fact it is perfectly suitable for either. There is much confusion in this way due to specifying materials that are not quite the same, as for example, the stretch of steel. One percent of variation in the stretch of steel will reject for one man and yet it will be perfectly satisfactory for another. Also in the use of standards for design there is much that can be saved. Standard beams and angles are more easily obtained and sometimes more economical to use. I have seen eye bars $3\frac{5}{8}$ by $\frac{9}{16}$ in. specified in a truss. Of course they would not be made that size, because they are

not standard. If designers would make a study of standards, they would very often save themselves trouble and their clients money. Sometimes requirements are given by an engineer with the idea that he is getting something better than another, when in fact it is not any better. He is using his professional judgment, which sounds well but costs his client money. Professional judgment is a good thing where there is not a good rule to follow. But if there is a good rule that has been tried and found satisfactory, it is often much better than professional judgment.

Mr. E. K. Hiles: There is one phase of this question which the speaker believes worthy of more attention than is usually given to it. In purchasing material, particularly finished product, much loss of time, money and prestige may frequently be avoided by making an inspection of a bidder's *plant* as well as an examination of his *product* in order to be certain that the requirements of design, time of delivery; workmanship, finish, etc., will be met commercially. It frequently happens that orders are placed in shops where the physical limitations of the plant preclude turning out the products on a sufficiently large scale to meet the commercial requirements of the purchaser. Instances are not lacking where the actual loss to the purchaser in such cases has been not inconsiderable.

The opportunity afforded on such an inspection trip in bringing the purchasing engineer in direct contact with the manufacturer or producer, as pointed out by the Author, usually brings about an exchange of information which frequently results in an entire change of base of the part of one or the other with consequent good results.

THE PRESERVATION OF STRUCTURAL TIMBERS FROM DECAY

By C. P. Winslow.*

The preservation of timber from decay by injection with chemicals, although largely practiced in Europe for many years, has only developed extensively in the United States within the past decade. Largely on account of the extensive supply of timber and the corresponding low cost, little attention to the conservation of the forests and their products was thought necessary. The consumer could see no immediate economy in increasing the initial cost of the product in order that a longer service might be secured. The supply was plentiful, and when timbers were rendered unfit for further service by decay and other destructive agencies, others could be readily and cheaply secured. Of recent years, however, these conditions have changed. With a diminishing supply and increasing demand for timber, there could be only one result—an increase in cost. In 1900, the average value for lumber at the mill was $11.13 per M. ft. B. M.; in 1908, it was $15.37, an increase of over 38 percent in eight years. Correspondingly, the practice of wood preservation methods has increased. While in 1904, less than 30 treating plants were in operation, there are at present 78 either completed or under construction. This increase in plants of over 160 percent in six years is only natural. The consumer is coming to the realization that for many cases there is no longer a question as to whether or not wood preservation will pay, but rather what method or process will give the best returns. There are, of course, a variety of preservatives and processes now used commercially, of which some are best suited for one purpose, some for another, and the selections must depend upon the feat-

* Engineer in Wood Preservation, Forest Service.

ures of each individual condition. There are, however, certain well-established principles upon which depends the success of any treatment. It is the purpose of this paper to briefly point out these principles and discuss the preservatives and processes now in general commercial use.

WOOD STRUCTURE AND CAUSES OF DECAY

Before considering methods for preventing decay, the general structure of wood and causes of decay should be understood. Briefly then, wood is composed of a series of long, close tubes extending parallel to the long axis of the tree. These tubes, sometimes known as vessels and tracheids, are firmly united laterally and fitted together endwise in the form of a splice. Moisture or water is contained in the individual cells and intercellular spaces, as well as in the cell walls themselves. When first cut, a large amount of this water in the form of sap is present in the wood, which is said to be green. Later, as the moisture disappears by evaporation, the wood becomes seasoned, a purely relative condition depending upon the size of the timber, length of time seasoned, and atmospheric conditions. In general, however, structural timbers having a moisture content of from 15 to 25 percent, are considered well seasoned.

Contrary to a somewhat popular understanding, decay is not due to an internal disintegration of the wood fiber of its own accord, but is produced by the action of low forms of plant life which feed upon the wood cells and their contents and cause disintegration. These organisms are commonly known as bacteria and fungi. Little is now known of the true action of the former, but for practical purposes it is probably similar to that of the fungi. This organism develops in the wood in the form of minute threads. Collectively known as "mycellia," these threads frequently form on the outside of the wood what is termed as the "fruiting body," familiar examples of which being the toadstool-like growths so often seen upon railroad ties and other timbers affected with decay. From the "fruiting bodies" come the spores, which are blown

about by the wind and attack the various forms of wood suitable for their development.

Necessary for the development of the fungi, however, are requisite amounts of air or oxygen, moisture, food, and heat. The complete elimination of any one of these factors will prevent decay. Illustrative of this is the long life of timbers completely buried in the ground or submerged under water, under which conditions there is an insufficient supply of air or oxygen for the development of the fungi. For most conditions, however, it is only feasible to destroy the food supply by impregnating the wood with materials poisonous to the fungi; it is on this theory that modern methods of timber preservation have developed.

SELECTION AND PREPARATION OF MATERIAL FOR TREATMENT

The success of any preservative treatment depends very largely upon the proper selection of the material. First, it is essential that the species selected be adapted to impregnation; and secondly, it is preferable to treat those species not naturally resistant to decay. Fortunately, these two conditions, poor decay-resisting properties and ease of impregnation, are closely allied. It is generally known that the heartwood of practically all woods is more naturally durable than the sapwood; so also is it more difficult to impregnate. Considering further, it develops that of the various species, the more naturally durable are also the more difficult to impregnate. For example: White oak and longleaf pine are durable timbers, containing relatively small amounts of sapwood. They are also of slow growth and corresponding high value. Experience has shown them difficult to satisfactorily impregnate. On the other hand, the quick-growing and nondurable loblolly and shortleaf pines, with their relatively large amounts of sapwood, can be readily and satisfactorily treated with a preservative.

Of equal importance to the selection of the material is its preparation. As previously pointed out, all wood contains more or less moisture. By one means or another, it is

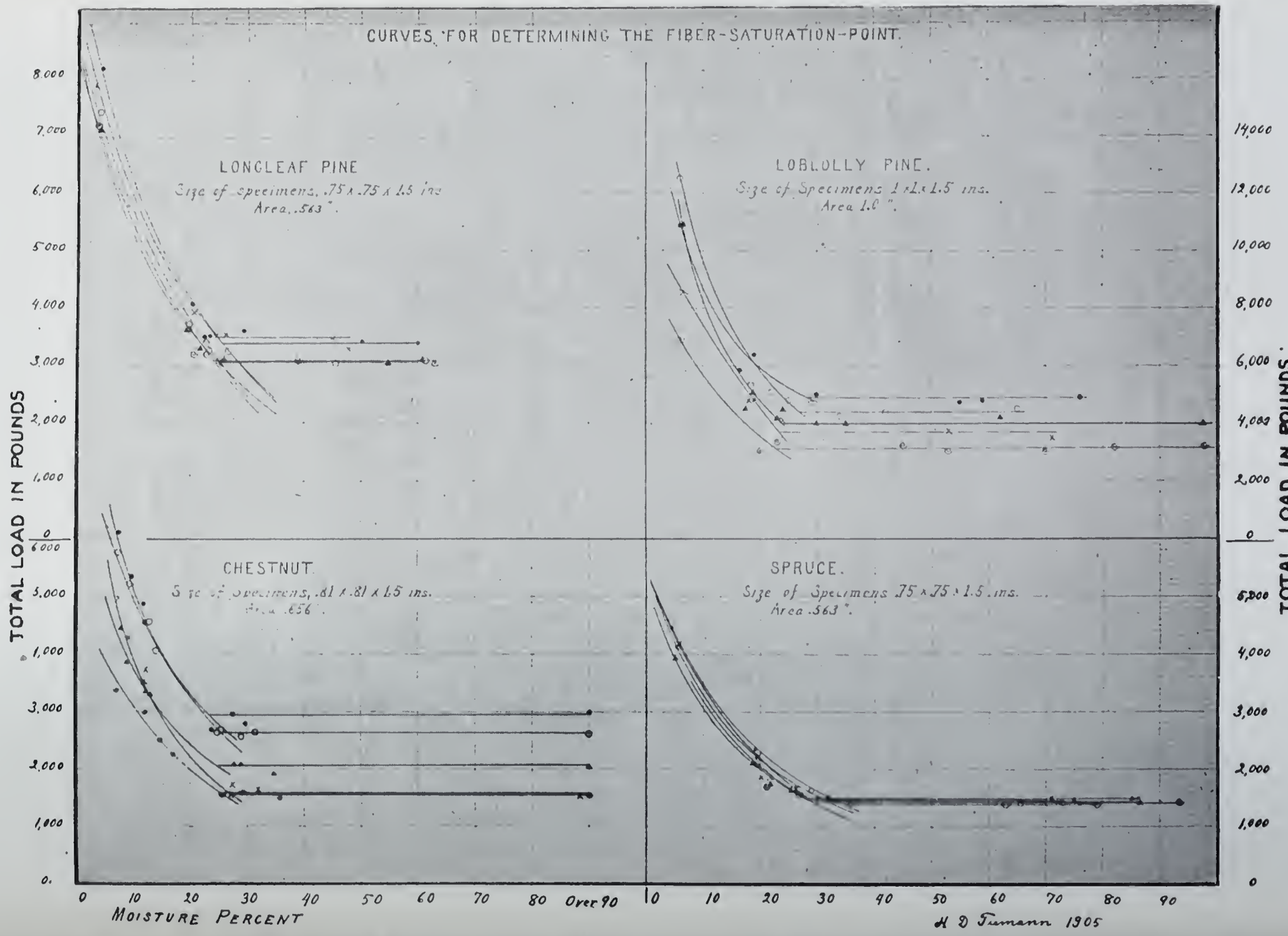

CURVES FOR DETERMINING THE FIBER-SATURATION-POINT.
LONGLEAF PINE
Size of specimens, .75 x .75 x 1.5 ins
Area, .563".
LOBLOLLY PINE.
Size of Specimens 1 x 1 x 1.5 ins.
Area 1.0".
CHESTNUT.
SPRUCE.
Size of Specimens .75 x .75 x 1.5 ins.
Area .563".
TOTAL LOAD IN POUNDS
MOISTURE PERCENT
0 10 20 30 40 50 60 70 80 Over 90
H D Tiemann 1905

Fig. 1. Illustration of the effect of moisture upon the strength of timber.

essential that much of this moisture be removed before the preservative can enter. In other words, the material must be seasoned. It is generally known that proper seasoning will greatly increase the strength of timber, but it is probably not so generally recognized that it is only after the evaporation of the free water from the intercellular spaces, corresponding to a moisture content of from 20 to 30 percent for different woods and termed the "fiber saturation point," that the quantity of moisture will affect the strength. The curves in Fig. 1 show the effect of moisture upon the strength of longleaf pine, loblolly pine, chestnut and spruce timber.

Mr. Harry Donald Tiemann, who established this point several years ago, has more recently carried on investigations which indicate that at this same fiber saturation point, the internal cell walls of the wood minutely check and split, which would seem to explain the necessity for seasoning prior to impregnation.* Also, this indicates the necessity of seasoning only to the fiber saturation point, since at this point the free water has been exhausted from the intercellular spaces, and the cell walls themselves have split sufficiently to admit the passage of the preservative.

The first step in seasoning timbers is to remove the bark; unpeeled timbers can season only through the small areas of the exposed ends. The advantages of so doing are several. First, unless the bark is removed, seasoning will not satisfactorily advance. Secondly, preservatives can not be forced into bark. Unpeeled timbers, therefore, can not be successfully impregnated. Strange to say, this applies to the thin inner skin as well as to the main body of the bark. This is well illustrated in Fig. 2 which is a photograph of a section of a creosoted pine tie. The unpenetrated streak across the section was due to the presence of a small strip of the inner skin which adhered to the surface of the tie during the treatment.

Finally, peeling increases the natural life of the timber, and for this reason may be considered as the most simple method for preventing decay. It is estimated that by peeling alone.

*See Vol. 7, Proceedings of the American Society for Testing Materials, 1907.

the durability of timber will often be increased as much as 50 percent. Illustrative of this are the results of an inspection made by the writer of the timbers used in several coal mines in Illinois; of many peeled and unpeeled timbers, set under similar conditions and about the same date, extensive decay was found only in the latter; there was practically no decay of the barked timber.

Fig. 2. Section of creosoted pine tie. Note unpenetrated streak due to adherence to surface of inner skin of bark.

Subsequent to peeling, there are several ways in which the timber may be seasoned. The most general and satisfactory method is to stack in plies and allow to air-season. The method of piling and duration of seasoning will, of course, depend upon the size, form, and species of timber, and the local weather conditions. Under all conditions, however, it is essential

that the material be so piled as to admit the ready circulation of air and to provide for drainage of water. Fig. 3 shows a good method of piling ties to secure rapid seasoning and prevent incipient decay. Care must be exercised to prevent excessive checking of the material through too rapid seasoning. Figs. 4 and 5 show an exaggerated case of this checking, and a method for preventing it by the use of *S* irons.

In the South, especially with such material as red and black oak ties, this trouble is of considerable importance, and the *S* irons or "Stop-crack hooks" are extensively used at a cost of about one cent each, which includes placement on the tie.

Other drawbacks to the air seasoning of timbers are the interest charges for from two to six months on an investment equal to the value of the material in question, and the tendency for incipient decay or dry rot to affect the timber. Commercial plants, especially in the South, often can not afford to air season their material on account of the loss due to the latter cause, and for this and other local conditions, recourse is frequently had to artificial methods such as steaming or boiling the material in the preservative prior to impregnation. With woods resistant to impregnation, such as the heart of longleaf pine, it is necessary that some such methods be used to secure a satisfactory penetration of the preservative. The experiments of Mr. Tieman, before referred to, indicate that steaming will cause checking of the cell walls of the wood similar to that caused by air seasoning. For general conditions, however, it is now the consensus of opinion that not only will the treatment of air-seasoned stock be more satisfactory than of green, but the actual cost will be less. Mr. F. J. Angier, Timber Engineer of the C. B. & Q. R. R., in a recent article presented before the New York Railroad Club, estimates this difference at about one cent per tie.

PRESERVATIVES

The preservatives in general use may be divided into two main classes; viz., oils and salts. Of the former, coal tar creosote or dead oil of coal tar is undoubtedly the most widely used and generally recognized as an efficient preservative. Pro-

duced as it is by the distillation of coal tar, its constituents are most complex, depending upon the character of the coal, temperature of coking, and temperature limits of the distillation of the tar. In general, however, the commercial product is the distillate coming over from the tar between a temperature range of from about 200 to 350 deg. cent., and consisting of varying

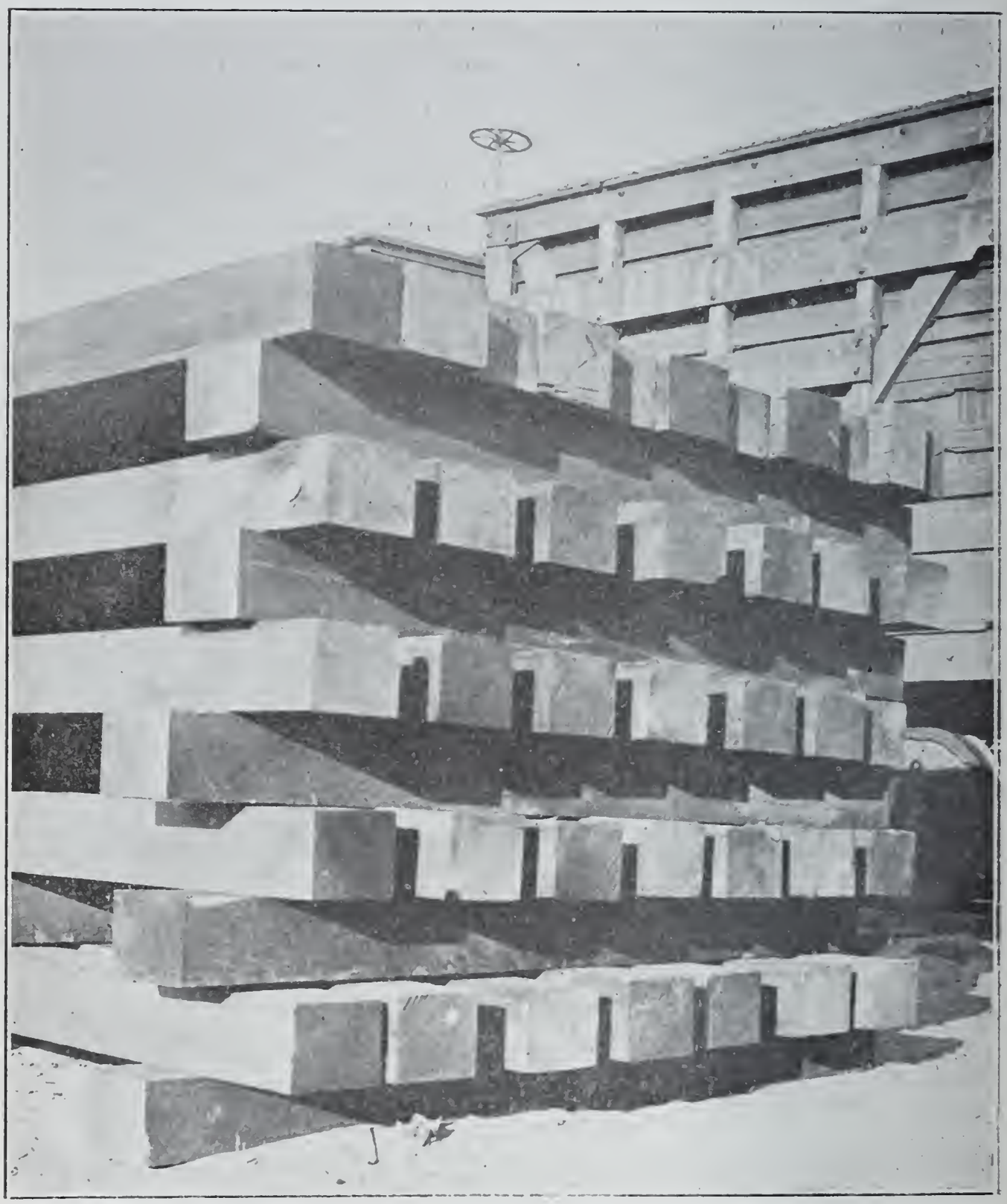


Fig. 3. Method of piling ties to secure rapid seasoning and prevent incipient decay.

amounts of phenols, or tar acids, naphthalenes, and anthracenes, and their compounds. The merits of these various constituents are open to much discussion. Formerly, it was believed that the phenols or tar acids were the important factors, but an analysis of the oils extracted from creosoted timber after many years service show no such acids present, they doubtless having been lost through volatilization. So also, naphthalene, which forms a very large part of the creosote manufactured in this country, is extremely volatile, and it is doubtful if, under general conditions, this will remain in the timber for a long period. It is, however, insoluble in water and is believed by many to be the most effective preservative in preventing the ravages of marine borers into piling. For most purposes though, the anthracene fractions are probably the most permanent and lasting in the wood, and creosotes containing relatively large percentages of these fractions are generally considered the more desirable. Unfortunately, since the production of creosote in this country is secondary to that of soft pitch, the distillation of the tar is not generally carried to sufficiently high temperatures to drive over a large percentage of the anthracene. In Europe, however, where the aniline dye industry is of prime consideration, the commercial creosotes contain a much larger percentage of anthracene. As a rule, therefore, the foreign oils are of a superior grade to those produced in the United States. It is interesting to note that in 1909, 73 percent of the creosote used in this country was imported.

There is another creosote produced from the tar resulting from the manufacture of illuminating gas from petroleum, which is very similar to the coal tar product. Generally known as *oil-tar creosote* or *water-gas-tar-creosote,* it is used to some extent under its own name, but more frequently under the guise of coal-tar creosote. It is difficult to clearly differentiate between the two, the important difference being in the character of the hydrocarbons forming their constituents. Whether or not a coal-tar creosote is any better as a preservative than one from an oil tar, has not yet been definitely settled. Many claim that the latter will prove equally efficient, and it is known that much

of the product now sold under the name of coal-tar creosote consists largely of either oil tar or the creosote therefrom. On the other hand, the use of this material is too new for conclusive data as to its merits to have been secured, while there are many instances of extremely long service secured with timbers treated with coal-tar creosote. It is more than probable, therefore, that preference for this material will continue for some time to come. Appended to this paper are two specifications for

Fig. 4. Badly seasoned chestnut telephone pole.

coal-tar creosote; the first is that adopted by the American Railway Engineering & Maintenance of Way Association, and the second is one proposed for consideration by the Forest Service. A satisfactory grade of oil is doubtless covered by both specifications, but in the former no means for the detection of adulterations of petroleum products is given. Although the Forest Service method can not be said to definitely accomplish this under all conditions, it is yet believed that it covers a

creosote consisting in the main of the aromatic hydrocarbons. It is probable that difficulty will at present be experienced in procuring an oil which will conform to this specification, but it would seem that if pure coal-tar creosote, by which is meant one from a tar from high temperature coking, is specified, that there should be some means of determining whether or not such a product is supplied.

Within the last few years the use of crude oils as wood preservatives has also developed to some extent. The success of such preservatives depends primarily upon so plugging the pores of the wood that the admission of sufficient air and moisture for the development of decay is prevented. The oils do not possess antiseptic properties, and for this reason their ultimate success is still in question. The Santa Fe R. R. is experimenting on quite a large scale with such oil from Bakersfield, Calif., and a somewhat similar product known as "Ebano oil" which is procured from Mexico. Their experience seems to indicate that oils having an asphaltic base are of more value than those with a paraffin base. Pine and gum ties treated with the California product and laid in Texas in 1902, were inspected by the writer in September, 1909, and were found in excellent condition. The average life of untreated pine ties in this territory is only from 1½ to 3 years.

Wood creosote, or creosote produced from the distillation of wood tar, may also be mentioned in the class of *oil* preservatives. However, the production of this material is so limited that it can not at present be considered of first importance in commercial treatments.

Referring now to the use of chemical salts: The success of such material in preserving timber depends primarily upon the antiseptic properties of the salt and its solubility in water, and secondarily upon a number of points, such as the effect upon iron and steel as used in the construction of treating plants, and the presence of acids or other chemicals which will cause disintegration of the wood. For such causes as the former, the use of copper sulphate and mercuric chloride, both excellent antiseptics, has been practically abandoned. Zinc

chloride, however, has withstood the test of time, and is extensively used in this country. It is generally applied in the form of a 2½ to 4 percent aqueous solution, the aim being to inject about ½ pound of the dry salt to the cubic foot of timber. As with all salt treatments, the chief objection is the subsequent leaching from the timber after treatment. Eventually this will reach such a point as to leave the wood in-

Fig. 5. Successful use of S iron to prevent checking of pole while seasoning.

sufficiently protected from the attack of fungi, when decay will set in. It is evident that such a preservative is unsuited for timber to be used in damp and wet localities. It would never do for the preservation of piling. But when the material is to be placed in dry or arid regions, and when, aside from decay the mechanical life is limited, zinc chloride may be advantageously utilized.

In comparing the relative merits of coal-tar creosote and zinc chloride, the cost of each must be considered. Creosote, although without doubt the most effective preservative at present in use, is also the most expensive. At a cost in bulk of from 8¢ to 10¢ a gallon, there is seldom used less than ½ gallon to the cubic foot of timber, and generally it falls nearer one gallon, frequently more than that. On the other hand, with zinc chloride, costing about 4¢ a pound, it is customary to inject not more than ½ pound per cubic foot, and frequently less. It is evident from this that for timber whose mechanical life is such that the full benefit of the creosote can not be obtained, the greater economy will accrue from the use of zinc chloride, either alone or in combination with a small amount of creosote. This latter method is frequently employed with crossties, where the zinc chloride alone would not quite protect from decay throughout the mechanical life of the tie.

PROCESSES

In applying a preservative to timber, it is the prime object, first to secure a certain requisite absorption, and secondly, to distribute the preservative throughout the wood as uniformly as possible. There are a variety of methods for accomplishing these results, which may for convenience, be classified into brush, open tank, and cylinder treatments.

The first of these, as the name implies, consists of applying the preservative with a brush, in other words, merely painting the material. It is the most simple and also the cheapest in first cost. Also, it is the least efficient of the methods. Only small absorption and slight penetration can be secured with this method, and it is applicable for use only with preservatives of the oil class. Such treatment, however, is better than none, and for general conditions will more than pay for itself if properly applied. It is suited for the butt treatment of poles, posts, etc., when the quantity of material to be treated is insufficient to warrant the installation of a plant. When used, the preservative is applied hot, and at least two coats, preferably three, should be given.

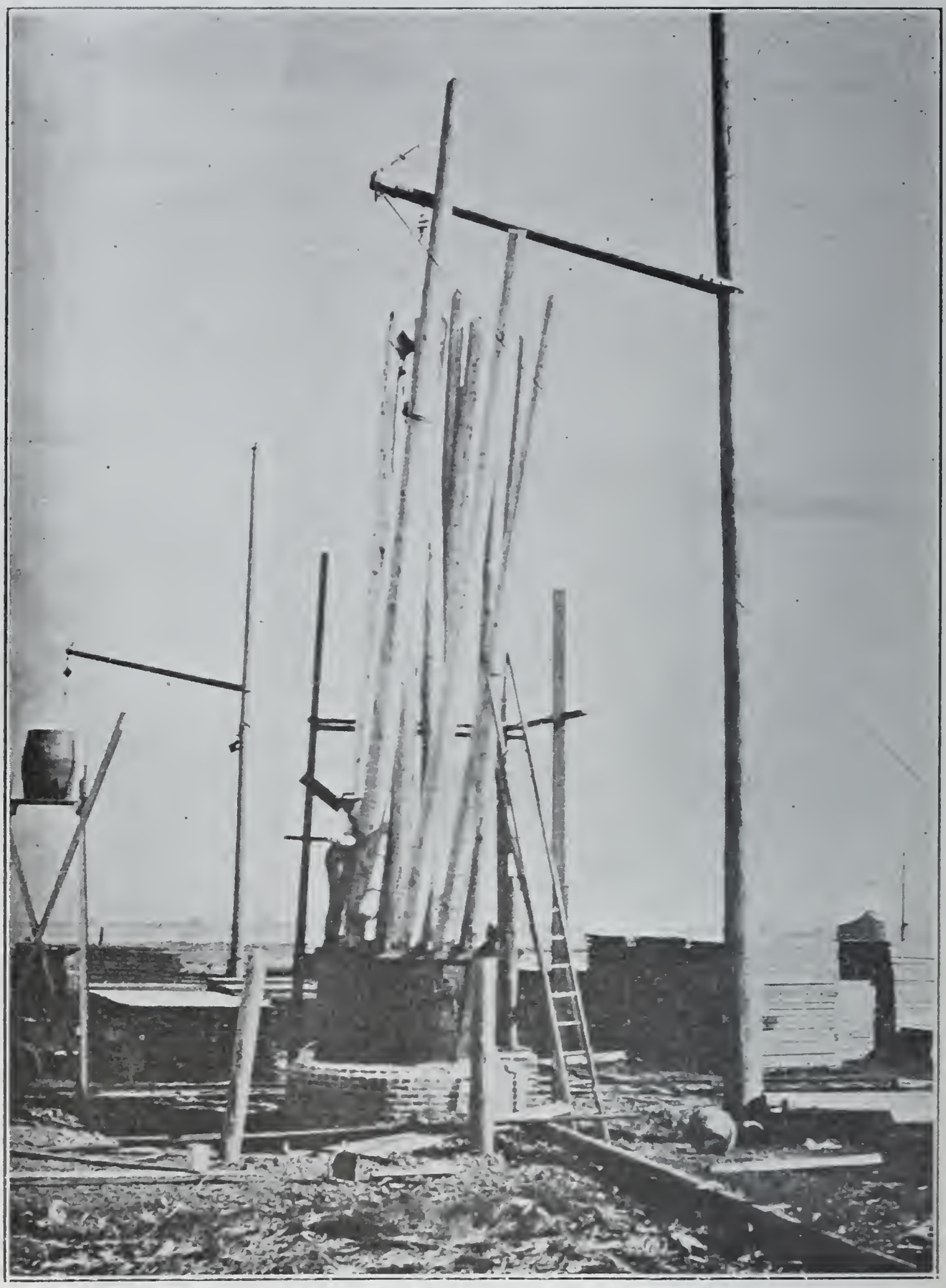


Fig. 6. Treating poles by open-tank method.

With the open-tank method, the material is submerged in a tank containing the preservative and is there boiled for a period varying from one to five hours, according to the character of the material and the absorption desired. This has the effect of expanding and driving out of the intercellular spaces of the wood a portion of the air and moisture therein contained. After this heating, the charge is either allowed gradually to cool in the preservative, or the hot preservative is quickly transferred from the heating tank, which is at once refilled with relatively cool preservative. During this cooling, the remaining air and moisture in the wood contracts, forming a partial vacuum, which is in turn destroyed by the entering preservative. This method of treatment is simple, requiring but little and inexpensive equipment. When only a small quantity of material is to be treated, a small metal tank with fire underneath is all that is required. A more efficient plant will consist of a treating tank fitted with steam coils for heating, storage tanks for holding the supply of preservative, a receiving tank into which the preservative may be quickly emptied at the expiration of the heating period, a small pump, boiler, derrick, etc. A combination of creosote and zinc chloride may be used by heating the charge in the former, and following by a cold bath in the latter. As with the brush treatment, this method is especially adapted for use with poles and posts. It is of distinct advantage in this connection, since the treatment of the entire pole is not desirable under most conditions. With loblolly pine and other woods having wide sapwood, very satisfactory penetrations may be secured by the open-tank method. Its chief disadvantages are the expense of handling the material, the time required for a treatment, and the loss of preservative through volatilization during the heating period. High boiling creosotes are recommended for use with this process. Fig. 6 illustrates the open tank method of treating poles.

Although the above two methods will serve the special purposes to which they are adapted, practically all commercial treatments of appreciable size are conducted under the *cylinder*

class. The material is here loaded on small trucks which are run into horizontal cylindrical retorts fitted with track and steam coils. The doors on the ends of the retort are then bolted, the cylinder is filled with preservative from the storage or measuring tanks, and pressure sometimes as high as 200 lb. per sq. in. is then applied to the charge with the force pumps. When the gauges on the measuring tanks indicate that sufficient

Fig. 7. Treating plant of Texas Tie and Timber Preserving Co., Somerville, Texas, where Rueping Process is used.

preservative has been forced into the material the pressure is relieved, the cylinder is emptied and the charge is removed. Many of these plants with their full complement of retorts, tanks, pumps, boilers, cylinder cars, derricks, locomotive cranes, storage yard, fire protection, and necessary buildings, cost several hundred thousand dollars, and have an annual capacity of nearly 10 000 000 cubic feet.

On the other hand, serviceable plants for the smaller consumer with capacities varying from 300 000 to 500 000 cubic feet, have been installed for from $10 000 to $20 000. The size of the treating retort is customarily six or seven feet in diameter, with varying lengths up to 132 feet. The more recent plants are being built with seven foot cylinders, which are evidently more efficient as to capacity than the smaller ones. Difficulty in handling the material off and on the cylinder cars apparently limits the practical diameter to seven feet. At the plant of the International Creosoting and Construction Company, at Texarkana, Texas, there is a retort 9½ ft. in diameter by 160 ft. long, but no other cylinder of such dimensions has ever been installed to the knowledge of the writer.

The details of treatment employed at the different plants are varied. The more important methods are in general as follows:

Full-cell Treatments: The object here is completely to fill the intercellular spaces with the preservative. If green timber is used, it is customary first to steam it in the retort by the admission of saturated steam at a pressure varying from 15 to 30 lb. per sq. in. In some cases, as with heart longleaf pine, this is continued for as long as 24 hours. It is followed by drawing a vacuum of from 26 to 28 inches in the cylinder, which is maintained for several hours, or until no more moisture can be withdrawn from the charge. Without releasing this vacuum, the retort is then filled with the preservative and pressure applied until the requisite absorption is secured. If the material is well seasoned, the preliminary vacuum is omitted. When the zinc chloride is used, this method is known as "Burnettizing" and is the most suitable process for this preservative. With creosote, it is termed the "Bethell" process. From long experience it is known to be effective. Likewise, due to the large consumption of creosote, it is expensive. For use with piling, it is however, admirably suited.

Empty-cell Treatments: In an attempt to reduce the high cost of the above method, while at the same time achieving its success, the empty-cell method has been developed. It is the

purpose of such treatments merely to coat or paint the cell walls with creosote as thoroughly as possible. In other words, a maximum penetration with minimum absorption is desired. Typical of this treatment are the Rueping, Lowry, and "creo-air" processes. Fig. 7 shows a photograph of a plant using the Rueping process, and Fig. 8 of a plant using the Lowry process.

Fig. 8. Treating plant of Shreveport Creosoting Company, Shreveport, La., where the Lowry Process is used.

The theory of the Rueping process is first to subject the material to an air pressure of from 65 to 75 lb. per sq. in. Without releasing this pressure, the cylinder is then filled with creosote, which is forced into the timbers with pressure varying from 100 to 175 lb. per sq. in., according to the nature of the material. Pressure is then released, the creosote run off, and a vacuum applied to the charge. This release of pressure

is said to permit the expansion of the compressed air forced into the timber during the preliminary stage, with a corresponding expulsion of the surplus or free oil. This method, first practiced in Europe, is now used extensively by the A. T. & S. F. R. Co., at their treating plant in Texas. With well-seasoned pine and gum ties, from five to seven hours are required for a treatment. In the Lowry Process, as used by the American Creosoting Company, the preliminary air pressure is omitted, and recourse is had to the compression of the air in the wood by the entrance of the preservative during the pressure period, followed, of course, by the final vacuum.

The "creo-air" method, although aiming at the same results as the Rueping and Lowry methods, is operated upon a different theory. In this case, only a limited quantity of the creosote is forced into the wood, after which the charge is subjected to a final air pressure. It is claimed by the advocates of this process that the effect of the final air pressure is to diffuse the creosote more thoroughly and completely throughout the wood.

Unfortunately, the development of the empty cell processes has only been within recent years. Their respective merits have not yet been conclusively determined. So far, timber so treated has given satisfactory results, but time only can definitely establish their merits.

Zinc-creosote Treatments: To overcome the leaching of zinc chloride from material treated with this salt, a treatment combining creosote with this chemical was introduced. As practiced in the South, this is known as the "Allardyce" process. It consists in first treating by the regular "Burnettizing" method, after which the charge is impregnated with from two to three pounds of creosote per cubic foot. With red oak, which is fairly resistant to impregnation, it is customary to air season the material for from two to three months subsequent to Burnettizing. This is to rid the timber of the free water, and permit the ready entrance of creosote in the final impregnation. It is evident that a prime objection to such a method is its expense. More recently, Mr. Card has developed a

process whereby the two preservatives are injected into the timber at one and the same time. In so combining these preservatives, the difficulty was to keep them in a proper and uniform emulsion, a difficulty due to the difference in the specific gravities of the two materials. Mr. Card has apparently overcome this by means of a centrifugal pump, the suction of which is attached to the top, and the discharge to the bottom of the treating retort. This is operated throughout the impregnating period, thereby keeping the preservatives well agitated and in emulsion. Timber treated by this process is used extensively by the C. B. & Q. and C. M. and St. P. R. R.'s.

Boiling Method: This deserves mention, since it is representative of the practice on the Pacific Coast. Here the charge is frequently treated green, and is first boiled in the creosote until the quantity of water given off from the cylinder,

Fig. 9. Decayed timbers in anthracite coal mine in Pennsylvania.

as determined by the discharge from a surface condenser, reaches a certain unit amount per hour. The heating is then discontinued, and the treatment progresses much as in the Bethell process. This treatment is somewhat similar in theory to that of the open-tank previously mentioned. The boiling period is primarily to season the material sufficiently to admit the preservative. As with steaming, care must be taken that the timber is not injured through excessive heating.

ECONOMIC ASPECTS

The successful development of any preservative treatment, of course, depends fundamentally upon the ultimate financial saving. A decrease in the costs must ensue to justify its existence. This ultimate reduction in costs rests directly upon two prime factors, viz, the relative durability and the relative first costs of the treated and untreated material.

There is practically now no question but that the natural durability of timber is much increased by the proper application of a preservative. In Europe, Baltic pine ties, well creosoted and protected by tie plates and screw spikes from rail wear, give a service of over thirty years. Pine piling, creosoted about 1879, and set in the waters of the Gulf of Mexico, is still sound, while untreated similar material is destroyed by the teredo in from one to three years, and creosoted timbers set in some of the coal mines of Pennsylvania were in excellent state of preservation after 14 years, although similar untreated timbers, set under similar conditions, were replaced three times in that period on account of decay. For general figures of this nature, the Committee on Wood Preservation of the American Railway, Engineering & M. of W. Ass'n., in its report presented at the annual meeting in 1909, gives the life of piling, treated with from 16 to 24 pounds of creosote per cubic foot, as 20 to 25 years; the life of properly creosoted ties, not protected from mechanical wear, as 15½ to 19 years; and the life of ties treated with from ¼ to ½ pound of dry zinc chloride per cubic foot, from 10 to 14 years. These are conservative figures, which will, of course, vary under different conditions.

The fact that more than 200 000 000 cubic feet of timber were used in the mines of this country in 1905, points to a wide field for the introduction of wood-preservative methods. In the coal mines of Pennsylvania, the conditions for the development of decay are almost ideal. There are many instances where untreated pine timbers have badly decayed within a year. Fig. 9 is a photograph taken in a coal mine showing decayed mine timbers.

Aside from the value of the timber, the cost of labor for replacement is a large expense, frequently equalling the cost

Fig. 10. View of creosoted pine pole near Norfolk, Va., after eighteen years' service.

of the timber. A preservative treatment of such timber need only increase its life for a comparatively short period to more than pay for itself. Unfortunately, mining companies have only recently begun to realize the importance of wood preservation, and conclusive data as to the relative merits of the various preservatives for this purpose is lacking. However, experiments conducted by the Forest Service in cooperation with the Philadelphia & Reading Coal and Iron Co., show that the many preservatives used in the experiments have all increased the life beyond that of the untreated timber.

The photograph shown in Fig. 10 indicates the advantages of treatment applied to telegraph and telephone poles. In this case, a creosoted pine pole near Norfolk, Va., was found in a perfect state of preservation after 18 years' service, while we know that similar material untreated will have a life of only 8 to 10 years.

As to costs, the initial expenditure for treated wood must of necessity exceed that for similar wood untreated. It is this which retards the development of wood preservation, but that the eventfual cost will be less is yearly becoming more generally recognized.

Let us consider the assumed case of a railroad operating 100 miles of track, using red oak ties. Allowing 2,800 ties per mile, a five years' life for the untreated tie, 50¢ for its initial cost, and 15¢ for replacement, then the cost in track will amount to 65¢ per tie, or an annual expenditure of $36 400. If the tie is creosoted at a cost of 35¢, the charge in place in the track will amount to one dollar. Assuming that five years will be required entirely to replace the untreated with treated ties, then the annual expenditure for renewals during that period would amount to $56 000. Allowing only fourteen years life for the creosoted material, there would then be a cessation of renewals for a period of nine years, when similar charges in a five-year period would again ensue. Allowing, therefore, 5 percent interest on the investment in each case, and substituting in the standard formula, given below, the annual charge for the treated tie is found to be $0.101, and for the un-

treated $0.15. Economy would result if the treated tie gave only nine years' service.

$$A = p \frac{(1+R)^m R}{(1+R)^m - 1}$$

A = annual charge
p = initial investment
m = number of years in recurring period
R = rate of interest, expressed decimally

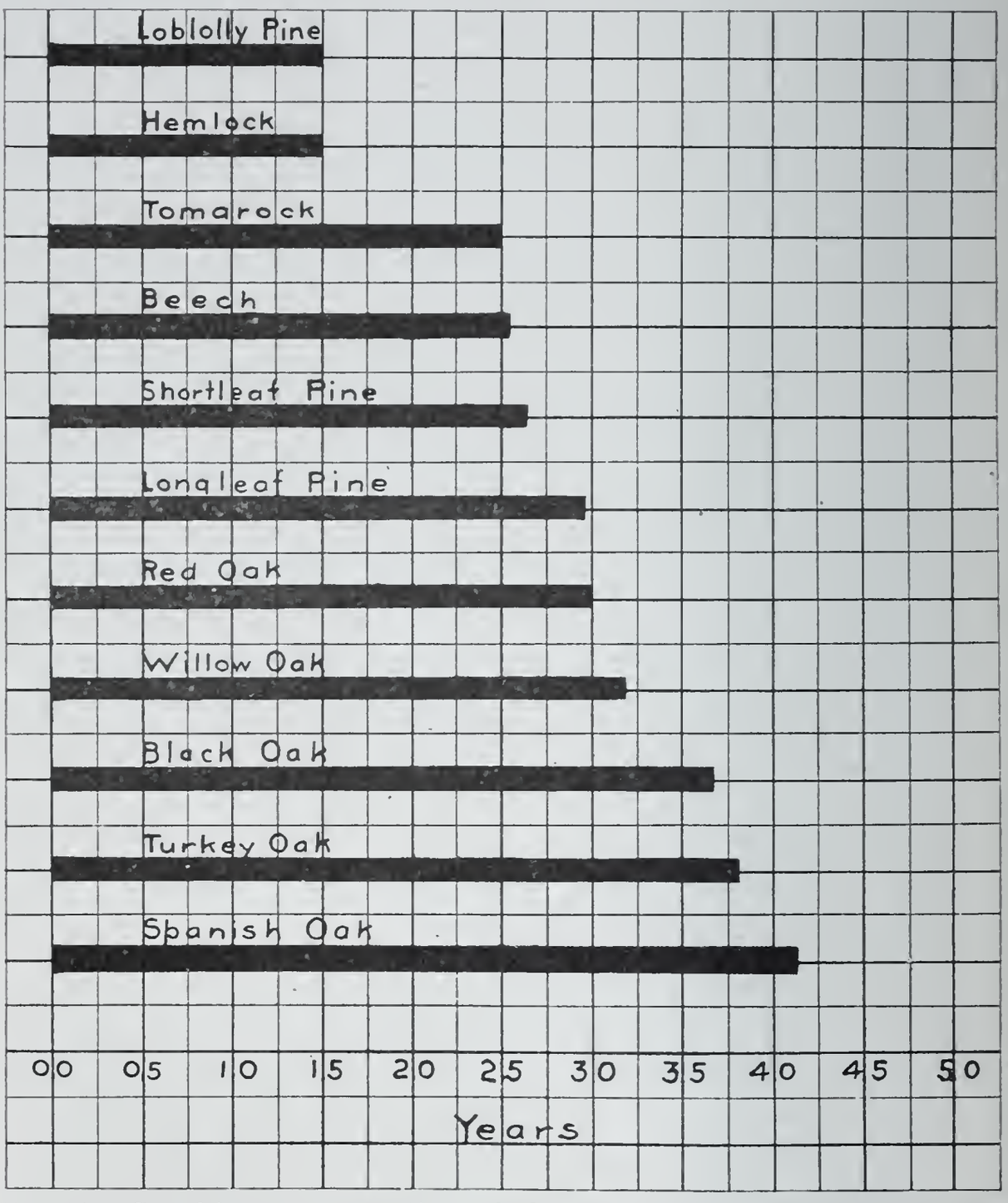


Fig. 11. Graphic representation of the average life of untreated ties in Texas. Compiled from records of tie removals in experimental track of the Gulf, Colorado & Santa Fe Ry. Co.

The above example only indicates the eventual saving which may be expected from wood preservation. The figures will, of course, vary for each and every problem or condition. If using the softer species, such as loblolly pine, tie plating is essential for the most efficient results. Such a tie properly treated and protected from mechanical wear, will far outlast the more naturally durable white oak. It is also cheaper, and the difference in cost of the two may well be expended in a preservative treatment of the inferior species. Finally, the supply of such durable timbers as white oak is diminishing, and recourse must sooner or later be had to the more plentiful and quick-growing woods. As a rule, these are well adapted to treatment. Fig. 11 is a graphic representation of the average life of untreated ties in Texas, compiled from the records of tie removals in the experimental track of the Gulf, Colorado and Santa Fe Ry. Co.

There remains one final factor affecting the economic aspects of wood preservation, which is the always increasing price of timbers. How great this increase will be is impossible to predict, but that it will continue is undisputed. In comparing the ultimate costs of treated and untreated timbers, we must, therefore, remember that the initial cost of timber necessary for replacements five or ten years from now will be much greater than at present, and every additional year of service which may be secured by the application of a preservative at the present time, will cause a financial saving equal to the difference between the present and the future cost of the untreated product.

COAL-TAR CREOSOTE SPECIFICATIONS

SPECIFICATION FOR A COAL-TAR CREOSOTE AS ADOPTED BY THE MAINTENANCE OF WAY ASSOCIATION

The oil used shall be the best obtainable grade of coal-tar creosote; that is, it must be a *pure product of coal-tar distillation* and must be free from admixture of oils, other tars or substances foreign to pure coal-tar; it must be completely liquid at thirty-eight (38) degrees centigrade, and must be free from

suspended matter; the specific gravity of the oil at thirty-eight (38) degrees centigrade must be at least 1.03. When distilled according to the standard method; that is, using an eight (8) ounce retort, asbestos covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil, the creosote, calculated on the basis of the dry oil, shall give no distillate below two hundred (200) degrees centigrade, not more than five (5) percent below two hundred and ten (210) degrees centigrade, not more than twenty-five (25) percent below two hundred and thirty-five (235) degrees centigrade, and the residue above three hundred and fifty-five (355) degrees centigrade, if it exceeds five (5) percent in quantity, must be soft. The oil shall not contain more than three (3) percent water.

Note: A revision of these specifications is now under advisement.

SPECIFICATION FOR GRADE *A* CREOSOTE PROPOSED BY THE FOREST SERVICE

The creosote should be derived from the distillation of pure coal tar and free from any adulteration whatever or any mixture of undistilled tar. If it contains more than 3 percent by-weight of water a deduction in price corresponding to the percent of water in excess of that amount will be made. It shall have a specific gravity at 60 deg. cent. of not less than 1.04. When analyzed by the standard Forest Service method of analysis for coal-tar creosote, it shall have the following fractions calculated on a moisture free basis*:

(a) Up to 205 deg. cent. not more than 5 percent.

(b) Up to 235 deg. cent. not more than 40 percent, nor less than 5 percent.

(c) Up to 250 deg. cent. not more than 50 percent, nor less than 15 percent.

(d) Up to 295 deg. cent. not more than 65 percent, nor less than 30 percent.

(e) At 355 deg. cent. the residue must be soft and not sticky.

On applying the sulphonation test to the fraction between 305 deg. cent. and 320 deg. cent. there shall be no oil residue insoluble in caustic alkalies.

*When less than 3 percent of water is present in the creosote it shall be considered moisture free.

The indices of refraction at 60 deg. cent. shall be as follows for the following fractions:

(a) At 250 deg. cent. not less than 1.593 nor more than 1.602.

(b) At 290 deg. cent. not less than 1.615 nor more than 1.622.

(c) At 300 deg. cent. not less than 1.625 nor more than 1.632.

Note: A revision of these specifications is now under advisement.

DISCUSSION

Mr. G. B. Shipley*: I met Mr. Raymer this afternoon and he requested me to come here to-night, so I am really not prepared. However, I will endeavor to give you a few details that have occurred to me.

Mr. Winslow's paper has covered the general experience of the United States as it is today.

The most important point about creosoting, or timber treating, is to know how much you are going to save. Railroad engineers, in investigating this subject, will first of all strike an average of the length of time an untreated tie will last as compared with a treated tie. I think it safe to assume about five years for an untreated tie and fifteen years for a treated tie in the United States. If you agree that as the result of treating, the ties will last fifteen years, the saving in rough figures will be about $100.00 per mile per year. Some will run above that, some below, but that is a pretty safe figure to use.

In looking through the Government records of timbers used in coal mines and making a rough comparison, I find that if we would treat the principal timbers used in mines, we could save about $12 000 000 per year in the United States alone; and that is treating only the permanent timbers, such as shaft timbers, ties underground and main run-way timbers. It of course would not pay to treat mine props or any timber subject to being covered up or lost in caving. I find that in some

* Engineer, Mining and Timber Treating Mach'y Dept., Allis-Chalmers Co., Milwaukee, Wis.

of the mines of this district the ties underground will last only two or three years. There is one mining company in the United States that is treating mine timbers thoroughly and that is the Philadelphia and Reading Coal & Iron Company at Pottsville, Pa. As Mr. Winslow says, they have found that it pays to give their main mine timbers a slight treatment of either zinc chloride or creosote at a cost of about $6.00 a thousand and they can save from 2½¢ to 3½¢ per cubic foot of timber going into the mine.

The question of treatment is one that has been carefully considered all over the United States and it has been resolved into the following important processes, using two antiseptics, creosote oil and zinc chloride:

1. Burnettizing Process.
2. Wellhouse Process.
3. Absorption Process.
4. Full Cell Creosote Process.
5. Rueping Process.
6. Lowry Process.
7. Card Process.

These processes, with the exception of the Absorption Process, are manipulated by mechanical contrivances such as pressure pumps, vacuum pumps, and air compressors and can be controlled to suit the wood structure, while in the Absorption Process the treatment is governed by temperature and atmospheric pressure, therefore is limited to certain woods.

Burnettizing Process: This is often referred to as the Zinc Chloride Process and consists of impregnating the wood fibres with a solution containing one-half pound of dry zinc per cubic foot of wood and is operated as follows:

The wood is first air seasoned in the open, or steamed in retorts to expel the moisture; then a vacuum is produced and maintained until the solution is introduced and the wood completely submerged. By pumping in additional solution the pressure is then increased to about 100 or 125 lb. per sq. in., until the required penetration and impregnation is obtained, when the remaining solution is drained from the retort.

Total time required to treat ties, omitting time of steaming, is about .....3½ hrs.
Total time required to treat ties including steaming time is .....5 to 7½ hrs.
Total time required to treat timber, omitting time of steaming is ..... 4 hrs.
Total time required to treat timber, including steaming .....8 to 12 hrs.

Wellhouse Process: This is often referred to as the Zinc Tannin Process and consists of impregnating the wood fibres with a hot solution containing about one half pound of dry zinc chloride plus one half percent of glue or gelatine per cu. ft. of wood, then following by injecting a second solution containing one half percent of tannic acid. The purpose of the tannin is to solidify the first injection to prevent leaching and is operated as follows:

The wood is first air seasoned in the open or steamed in retorts to expel the moisture. A vacuum is then produced and maintained until the solution is introduced and the wood completely submerged. The pressure is then increased to about 100 or 125 lb. per sq. in. by pumping in additional solution until the required penetration and impregnation is obtained, when the remaining solution is drained from the retort and the second movement takes place by filling the retort with a solution containing one half percent of tannic acid and increasing the pressure by pumping in additional solution at about 100 or 125 lb. per. sq. in. until the required penetration is obtained, when the solution is again drained from the retort.

Total time required to treat ties, omitting steaming is about .....4½ hrs.
Total time required to treat ties, including steaming is about .....6½ to 8½ hrs.
Total time required to treat timber, omitting steaming is about .....5½ hrs.
Total time required to treat timber, including steaming is about .....9½ to 13½ hrs.

Absorption Process: This is often referred to as the Non-Pressure Process and consists of submerging the wood in a boiling preservative at a temperature of about 230 deg. fahr., and then treating it with a cold preservative as follows:

The wood is first air seasoned in the open to reduce the moisture, then placed in either an open or closed receptacle where it is submerged in a hot preservative which expels the air and additional moisture. The receptacle is then drained and the wood submerged in a cold preservative. The first movement opens the pores or cells of the wood, forming a vacuum within, while the second causes absorption due to the difference in temperature and atmospheric pressure. This process can be used in either open tanks or closed retorts. For treating the butts of poles, fence posts, piling and small quantities of ties, the open tank is satisfactory, but for treating large quantities of material the closed retort is recommended where careful impregnation is desired.

The time of treatment is as follows:

For green timber:

Boiling in hot preservative from 8 to 10 hrs.
Bathing in cold preservative from 8 to 16 hrs.
Total time of treatment 16 to 26 hrs.

For seasoned timber:

Boiling in hot preservative from 3 to 6 hrs.
Bathing in cold preservative from 4 to 8 hrs.
Total time of treatment 7 to 14 hrs.

With this process it is possible to impregnate a limited class of woods with about 6 to 12 lb. of creosote oil per cubic foot.

Full Cell Creosote Process: This consists of impregnating the wood fibres and cells of ties with six to twelve pounds of creosote oil per cubic foot and timber and piling with 10 to 20 lb. of creosote oil per cubic foot, as follows:

The wood is first seasoned in the open or steamed in retorts (generally both) to reduce the moisture and expel sap, then a vacuum is produced and maintained until creosote oil is introduced and the wood completely submerged. The pressure is then increased to about 100 to 125 lb. per sq. in. and maintained until the desired penetration and impregnation is secured, when the remaining creosote oil is drained from the tanks. In some cases a vacuum is produced and maintained

at the finish to drain the surplus oil from the exterior of wood to prevent loss by drippage after wood has been removed from retorts.

Total time required to treat ties, omitting steaming ..... 3 hrs.
Total time required to treat ties, including steaming .....5 to 7 hrs.
Total time required to treat timber, including steaming .....7 to 11 hrs.
Total time required to treat piling, including steaming .....12 to 24 hrs.

Rueping Process: This is often referred to as a partial cell treatment and it is used principally in connection with creosote oil. It consists of forcing compressed air into the pores or cells of the wood and at a higher pressure creosote oil without relieving the air pressure. Upon relieving the combined pressure the air expands and forces out surplus oil, leaving the wood fibres impregnated as follows:

The wood is first air seasoned in the open or steamed in retorts (sometimes both) to reduce the moisture, then a vacuum is provided and the air is compressed to from 80 to 100 lb. per sq. in., thus filling all the wood cells with compressed air; and, by air equalizing reservoirs or pumps, the retorts are filled with oil without releasing the air pressure. The oil pressure is thus started at from 80 to 100 lb. per sq. in. and gradually increased to about 100 or 150 lb. per sq. in., having the effect of compressing the air in the cells to a smaller volume and permitting about 10 to 12 lb. of creosote per cubic foot to enter. The pressure is then released and oil drained from the retorts. A vacuum is then produced, which causes the air within the cells to expand and forces the surplus oil out of the wood, leaving the wood fibres impregnated with from four to six pounds of creosote per cubic foot. This process is best adapted for treatment of ties.

Total time required to treat ties, omitting time of steaming .....4½ hrs.
Total time required to treat ties, including time of steaming .....6½ to 8½ hrs.

Lowry Process: The Lowry process is a partial cell treatment process, it being used in connection with creosote oil. It consists of forcing creosote oil into the wood cells, and then drawing it out by vacuum, the surplus oil leaving only the wood fibres impregnated as follows:

The wood is first air seasoned in the open, then placed in retorts and submerged in creosote. The pressure is then applied and 10 to 12 lb. of creosote per cubic foot forced in at about 180 lb. pressure so as to saturate the pores and cells

Fig. 12. Pennsylvania Railroad Timber Treating Plant, Mount Union, Pa.

after which the retort is drained and a quick vacuum produced and maintained from one to two hours, leaving the wood fibres impregnated with from four to six pounds of creosote per cubic foot. This process is used principally in the treatment of ties.

Total time required to treat ties four to six hours.

Card Process: This method of treatment consists of impregnating the wood cells with an emulsion consisting of zinc chloride and creosote oil, as follows:

The wood is first air seasoned in the open or steamed in retorts (generally both) to reduce the moisture and expel the sap. Then a vacuum is produced and maintained for one hour, when the retort is filled with a hot emulsion consisting of one-half pound of dry zinc and from 1½ to 4 pounds of creosote per cubic foot. The pressure is then applied by forcing in additional emulsion at about 100 to 150 lb. per sq in., after which the retort is drained and a vacuum produced and maintained for about 30 minutes to draw the surplus emulsion from the exterior of the wood to prevent loss by drippage when the wood is removed from the retort.

It is necessary to keep the emulsion constantly agitated to prevent a separation of the zinc and creosote and to accomplish this a centrifugal pump draws the emulsion from the top of the retorts and discharges it into the bottom through a perforated pipe.

This process is used principally in the treatment of ties. Total time required to treat ties, including steaming 6 to 8 hrs.

Remarks: There is a great diversity of opinion among engineers and operators as to what is the best process or preservative to use, however, it is reasonable to assume that the foregoing are receiving the most favorable consideration by the leading railroads throughout the universe and especially in this country.

The question of treatment is resolved to a matter of investment and to secure the best results, the wood must be treated so that the chemical life will be equivalent to the mechanical life. Therefore, in considering this vital problem, the mechanical arrangements should be just as important as the treatment. In many instances the initial cost of treatment has been the important factor and the first cost of treatment will assume the following rotation:

1. Burnettizing Process.
2. Wellhouse Process.
3. Card Process.
4. Rueping and Lowry Processes.
5. Absorption.
6. Full Cell Process.

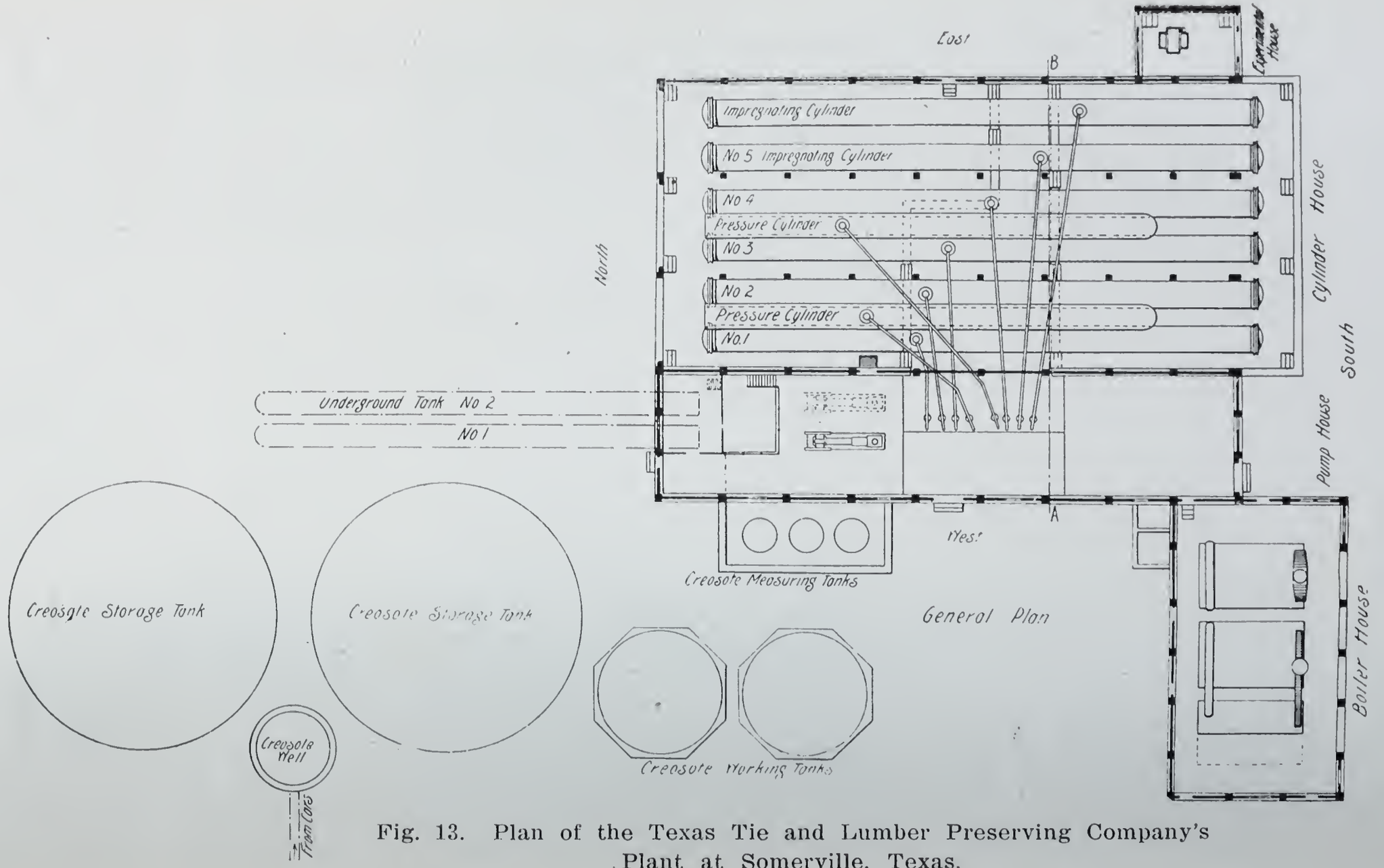


Fig. 13. Plan of the Texas Tie and Lumber Preserving Company's Plant at Somerville, Texas.

The full cell creosote process is the most expensive in first cost and is probably considered the very best for all conditions. It is particularly adapted for treatment of piling and timber, whereas the others are being used the most extensively in the treatment of ties.

The absorption process is advocated by some engineers as a very cheap installation and satisfactory treatment for general work and where small quantities are to be treated and time is of no consequence, but it is not a thorough success for plants that handle large quantities and where absolute control of treatment is desired. To secure uniform impregnation, it is obviously necessary to use mechanical apparatus.

From modern practice it is evident that the partial treatment for ties and full cell treatment for piling and timber is the most favorable among consumers.

It may be of interest to you gentlemen to know what the different railroads and commercial companies are doing throughout the United States. It is always best to start at home. The P. R. R. Lines East took up this matter about two years and a half ago, since which time they have installed a plant at Mt. Union, Pa., shown in Fig. 12, and another at Greenwich Point, Pa., just outside of Philadelphia. Each one of these plants will treat 500 000 to 600 000 ties a year. They are treating at Mt. Union mixed oak, beech, birch, gum, etc., and at the Greenwich Point plant principally sap pine and gum ties, timber, piling, poles and some blocks. Their present practice is to use from 8 to 10 lb. of creosote per cubic foot in treating ties.

The B. R. & P. R. R. started a plant at Bradford, Pa. in June. It is a small plant, having a capacity of about 300 000 to 400 000 ties per year, and they intend using from 8 to 12 lb. of creosote per cubic foot in their ties and 10 to 16 lb. in their bridge timbers.

The Eppinger and Russell Company's plant at Jacksonville, Florida, is a commercial plant and they are treating ties and material for the New York Central Lines, the Southern, Seaboard, the Atlantic Coast Lines, the Long Island, N. Y., N. H. & H. R. R. and many others. They also do a lot of foreign work

for shipment to Cuba and the South. They are able to treat with any process, but to date they are using the full cell process in nearly all their work, 10 to 12 lb. of oil for ties and from 16 to 24 lb. in piling.

The Somerville, Texas, plant of the Santa Fe Railroad is possibly the largest plant in the United States, for they treat about 15 000 ties a day. They have installed the Rueping Process, using four to six pounds of creosote per cubic foot. They also treat considerable timber and piling. The Santa Fe Railroad also have a plant at Albuquerque, N. M., where they are using the Rueping and Full Cell Processes and are experimenting with crude oil treatment using California crude oil plus 30 percent of creosote, and get a very good treatment.

The Illinois Central R. R. purchase a great many of their treated ties from the Ayer and Lord Tie Company, who have plants at Carbondale, Ill., Argenta, Ark., and Grenada, Miss. They are using the Burnettizing, Rueping and Full Cell Processes, depending on where material is used. In the North they use the lighter treatment for the reason that in the South the tie will last less than half as long as it will in the North.

The Southern Pacific have one plant at Los Angeles, Cal., one at Oakland, Cal., and another in Oregon. They are treating ties with ¼ to ½ lb. zinc chloride per cu. ft. It gives a cheap Burnettizing treatment and they seem satisfied. They are one of the oldest railroads in the United States using the zinc chloride process. In fact Mr. Isaacs, the Consulting Engineer, was the original patentee of some of the machinery used in the process and great credit is given him for working up the original plants.

The Salt Lake Route has a plant at San Pedro, Cal., using the zinc chloride process. The Creosoting treatment on the Pacific Coast is somewhat different from other places. The Pacific Creosoting Company at Eagle Harbor, near Seattle, Wash., are using the boiling process and it seems to be the only process that is satisfactory for treating fir timber, for it is a very difficult wood to treat. The fibers and cells are constructed different from the woods we have in the East and

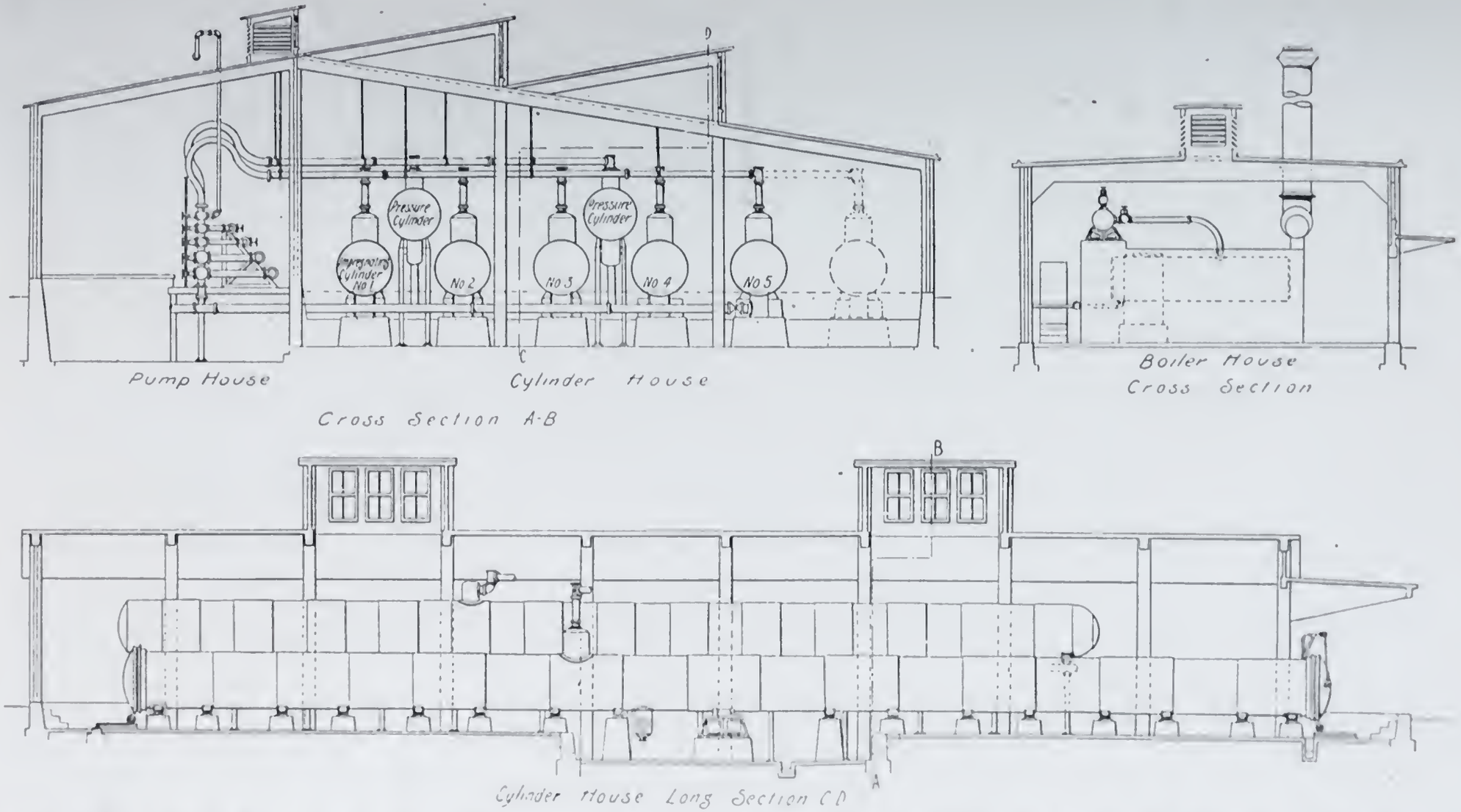
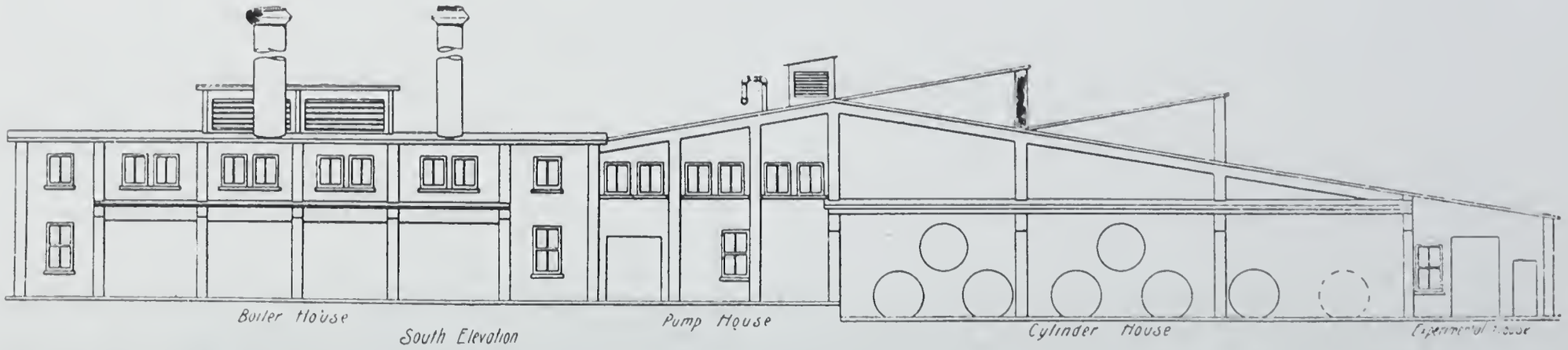


Fig. 14. Cross Section of the Texas Tie and Lumber Preserving Company's Plant at Somerville, Texas.



South Elevation

Fig. 15.. Cross Section of the Texas Tie and Lumber Preserving Company's Plant at Somerville, Texas.

South and there is so much pitch in the wood that it is hard to penetrate and in order to secure thorough penetration they find it necessary to immerse the wood in creosote, gradually heating it to a temperature of about 180 to 225 deg. and maintaining boiling temperature from 10 to 30 hours, depending on the wood. Thus they boil out the moisture and sap and then treat it with either the Rueping or the Full Cell Process, principally the latter. They are treating material for China, Japan and South America and for the railroads and dock companies along the Pacific Coast.

To show how important it is to creosote piling on the Pacific Coast, an untreated pile in San Francisco Bay will only last about nine months. If it is creosoted with only 10 to 12 lb. of oil per cubic foot it will last 10 to 20 years. They have creosoted piling in the Southern Pacific wharves that have been in place 10 years, and untreated piling near by have gone out in less than a year. The Teredo attacks internally, below the low water line, and above the low water line the Limnoria externally.

The Chicago & Northwestern Ry., at Escanaba, Mich., are using the Card Process. They used the Wellhouse process for a good many years, but gave it up some time ago for the Card Process. They use ½ lb. zinc per cubic foot in a solution of water and oil, the oil amounting to about 1½ to 4 lb. of oil per cubic foot, depending on the material.

The Chicago, Milwaukee and St. Paul R. R. are using the Card Process and are having the material treated by the Chicago Tie & Timber Company, Mr. Card, the patentee. He also has a plant at Terre Haute, Ind., using the same process.

The C. B. & Q. R. R. have a plant at Galesburg, Ill., in which they use the Card Process for ties; and Full Cell process, using creosote, for timber. They have another plant at Sheridan, Wyoming, using the Burnettizing Process.

Some of the principal commercial plants are the National Lumber and Creosoting Company, and the International Creosoting Construction Company, Texarkana, Texas; the United States Wood Preserving Company, the Norfolk Creosoting Com-

pany, and the Atlantic Creosoting Company, Norfolk, Va.; the Eppinger & Russell Company, Jacksonville, Florida; the Gulfport Creosoting Company, Gulfport, Miss., and the Kettle Rivers Company, Madison, Ill. The plant of the Texas Tie & Lumber Preserving Company's plant at Somerville, Texas, is shown in Figs. 13 to 19 inclusive.

It might be well to mention that Pittsburgh will have a plant near Connellsville, Pa., within the next few months, arranged to treat timber with all modern processes.

The question of treatment depends entirely on the location of the ties or timber, the load on the tie, whether you are going to use tie plates, screw spikes or ordinary spikes, etc. It is reasonable to assume that if you have a light load on the rails, a small tie with a light treatment can be used. If a heavy load on the rails, a large tie and tie plates with heavier treatment, equivalent to the mechanical life. In other words, the chemical life should be equivalent to the mechanical life. Selection of processes in many cases is a matter of opinion. But we know that creosote will increase the life and it has been used in this country for a great many years. Further, in Europe, ties have been in the road thirty years.

There are several new processes that have come up in the last few years, among which I might mention the creosote-calcium process, which consists of the elements of creosote, together with lime in a solution. That is a patented process now advocated by the Blagden & Waugh Company of London. They have been experimenting in our country with some of the railroads, but it has not yet been favorably considered. Another process consists of a mixture of sulphur and lime, boiled into the wood. Then there is the Vulvanizing Process, which consists of coagulating the sap and vulcanizing under high temperatures. It is claimed that with this process the spikes hold better and it increases the strength of tie.

The only way we can find out whether these new processes are going to be of any value is to make a comparison test in a fungus pit. They have several in Europe and we now have one at the United States Forestry Department Experiment-

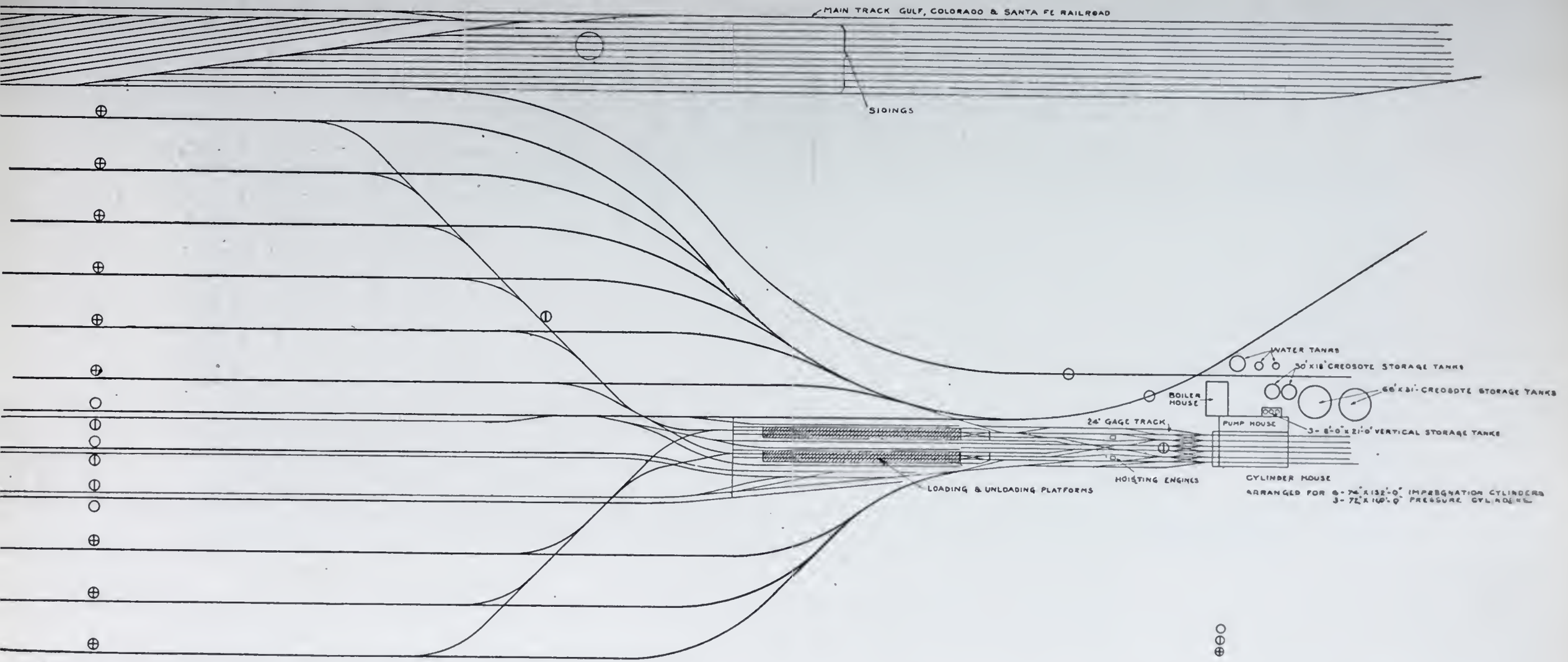


Fig. 16. Plant and Track Arrangement of the Texas Tie and Lumber Preserving Company's Plant at Somerville, Texas.

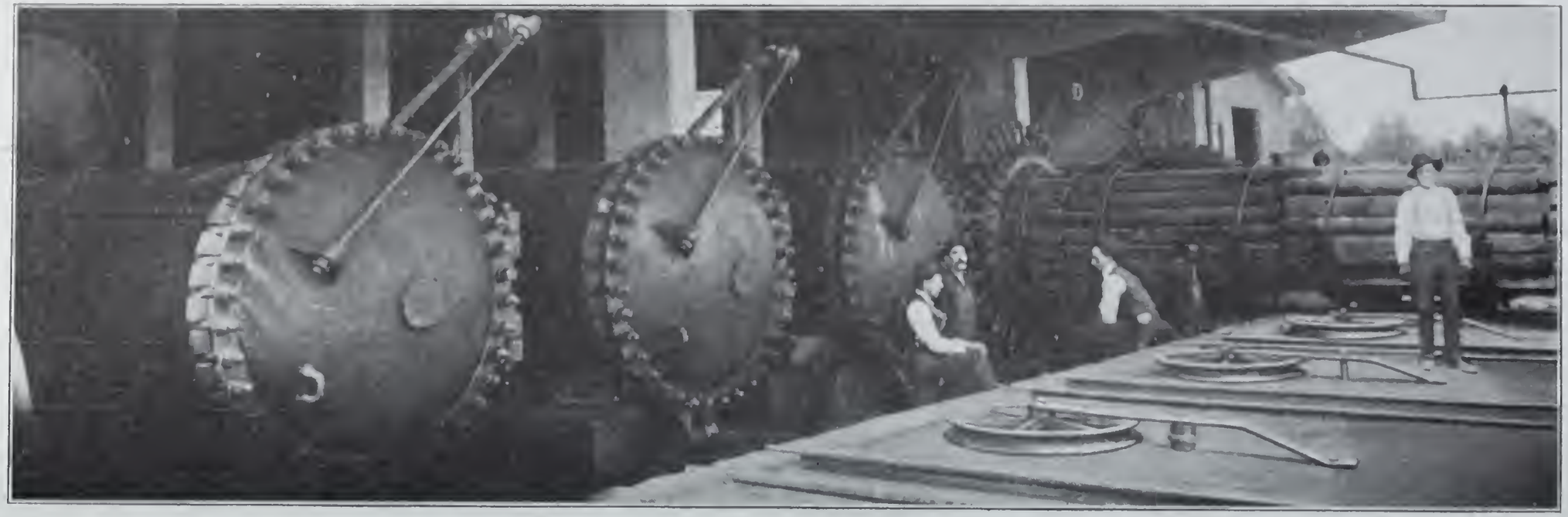


Fig. 17. End View of Cylinders in the Texas Tie and Lumber Preserving Company's Plant at Somerville, Texas.

al Laboratory at Madison. The Madison plant is one of the best equipped experimental laboratories in existence. They have a very complete equipment and they are putting in a fungus pit, which means that they can then take all these different kinds of wood and treat them with different processes and put them in this pit, thereby being able to tell within three or four months which is the most valuable.

Fig. 18. Gauge Board Arrangement in Machine Room in the Texas Tie and Lumber Preserving Company's Plant at Somerville, Texas.

The treatment of telephone and telegraph poles is very important. You have all probably noticed that the poles throughout the country will begin to decay at the ground and within three or four years they will rot away until they are only three or four inches in diameter. There is a new method of treating poles which is going to be very successful. It is the Logan system, see Fig. 20, and consists of putting the pole in a closed horizontal cylinder, then tilting the cylinder up on end and allowing the oil to go into the bottom up to any height desired, five, six or eight feet; then put an air pressure on top of that oil, which keeps the oil at uniform height and force the oil in with a pressure pump until you get the desired penetration. The pole which was shown on the screen was

treated its full length in a closed cylinder. With this new process they can treat $\frac{1}{3}$ or $\frac{1}{5}$ of the pole, thereby effecting a considerable saving.

Poles in the ground can also be protected if they go at it in time by the Lamb Process, which consists of digging around the pole and putting in a form and pouring asphalt mixed with creosote into this form and placing a collar of concrete at the ground level. That has been tried on the Pennsylvania Lines and seems to be much in favor.

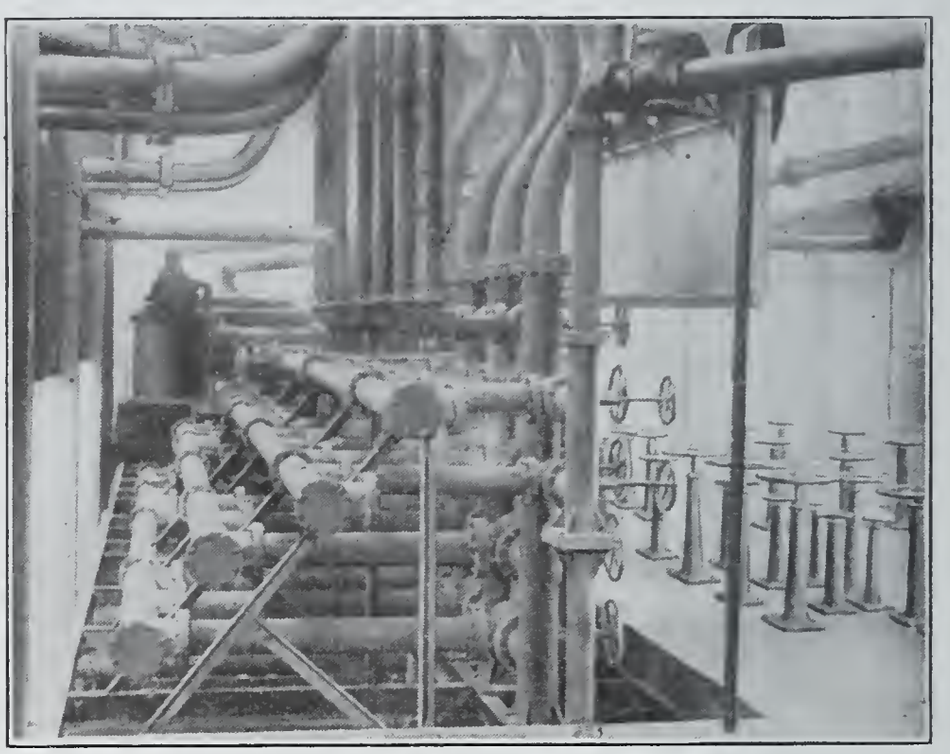


Fig. 19. Pipe Arrangement in Machinery Room in the Texas Tie and Lumber Preserving Company's Plant at Somerville, Texas.

The producers of creosote in the United States, up to a few years ago, were unable to make creosote oil of standard specifications as compared to creosote oil secured in England and Germany. However, the producers in the United States now agree to make creosote oil to any reasonable specifications, the same as European oils. In fact about 35 percent of the oil is produced in the United States now and they are making arrangements to produce more.

The creosote oil that is brought to this country is brought over in tank steamers. It is kept at a temperature of about 125 to 135 deg. fahr., and delivered in tanks at Philadelphia, New

Orleans, Galveston, Gulfport and Jacksonville, Fla. Creosote oil costs, in the United States, from 6½¢ to 7¢ per gallon, on the coast.

The treatment of blocks in the United States is becoming very important. The cities of New York, Philadelphia, Cincinnati, St. Louis, Chicago, Minneapolis and many of the Western cities are taking it up very rapidly. Some plants are devoted exclusively to the treatment of blocks and there have been some blocks put in the streets of Pittsburgh I believe.

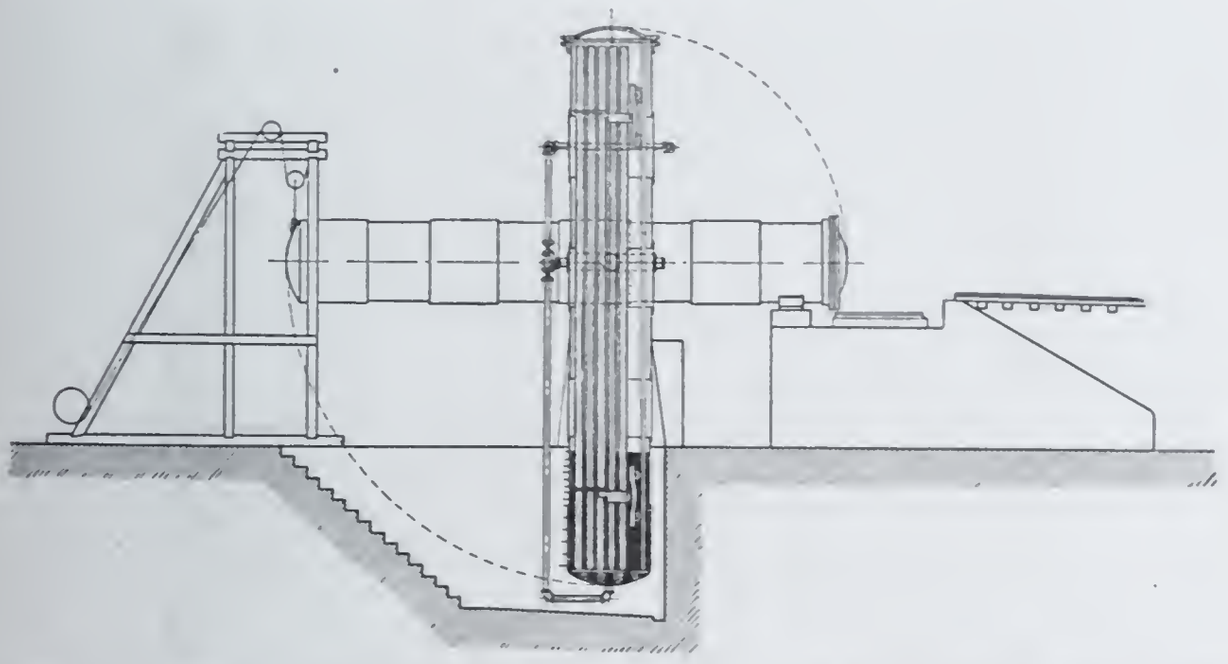


Fig. 20. Tilting Cylinder, 74 in. by 40 ft. used for treating the butts of poles.

Chairman V. R. Covell: It is fitting to add that Mr. Shipley has been modest in his statement and that he is to install and operate this new plant at Connellsville.

Mr. G. S. Davison: I would like to ask Mr. Shipley if he has any ideas in regard to the question whether the heavier treatments have a deteriorating effect on the timber. In discussing this with engineers who have used heavy treatments, about 24 lb., they give it as their opinion that such heavy treatment makes the wood brittle.

Mr. G. B. Shipley: Yes, high pressure will have a tendency to fracture the fibers of the wood. The usual practice throughout the United States is to use not over 200 lb. pressure

per square inch on the timber. There have been some tests made at higher pressures and they have found that the high pressures do fracture the fiber. The full cell creosote process will have an average pressure of about 180 lb. to the square inch.

MR. G. S. DAVISON: I would also like to ask if I understood aright that the Teredo attacks the pile between high and low water. I had understood that the Teredo does not attack piling above low water mark but remains several feet below.

MR. G. B. SHIPLEY: Possibly I did not explain that in detail. The Teredo will attack the pile as high as 18 in. above low water mark. The Limnoria attacks it between low and high water level.

MR. A. R. RAYMER*: The program committee is to be congratulated on securing this paper. It touches a subject which is a particularly live one among railroad men. The supply of timber under the rapid rate of consumption is becoming very scarce. It is very difficult to get good ties and the difficulty is increasing from year to year. As has been said by our Chairman, Mr. Shipley is very modest in speaking of the work he has done as he has installed, constructed, and put in operation many of the plants he has been speaking about tonight.

About a year ago I had the pleasure of visiting Mr. Crawford, President of the Tennessee Coal & Iron Co., of Birmingham, Ala., formerly of McKeesport. He said that when he took charge of that property the visible supply of timber for their mine and other work at that place would last only seven years. In the short time he has been there he has inaugurated a timber treating plant and a system of reforestration by which the same supply of timber will last his company perpetually. This gives an illustration of the importance of taking care of the timber and preserving it.

I came here tonight seeking information, not to give it. Our company has done very little so far in treating ties. The

* Assistant Chief Engineer P & L. E. R. R., Pittsburgh.

bridge ties on the Ohio River Bridge are treated. We treated them by the open tank process, using steam coils and Carbolineum Avenarius, a German product, heated to a temperature of about 200 deg., in which green, freshly sawed white oak ties were treated. It cost the company considerable money but it is estimated that if the life is prolonged as we expect it will be, the investment will be very profitable.

MR. V. R. COVELL*: The use of treated timber has not been extensive in the Pittsburgh District. One or two short stretches of street pavement and a few bridge floors will include about all that has been used. In 1909 the County Engineer's office adopted the policy of using only treated timber in the floor systems of old bridges where all timber must be renewed. The three County Bridges, Monongahela River Bridge No. 1, Allegheny River Bridge No. 1, and Ohio River Bridge No. 1, built recently or now building, are designed with treated wood block paving. There has been difficulty in getting reasonably prompt delivery of material. Sufficient time has not elapsed to determine the value of the treated timber in this construction.

MR. L. P. BLUM: Mr. Shipley has mentioned the treatment by the Pennsylvania R. R. of beech timber. I would like to ask to what extent and with what success beech timber has been treated and will it make good ties?

MR. G. B. SHIPLEY: Beech timber can be treated about the same as mixed oak. It has about the same structure, and takes about the same treatment; it will make a good tie and last about as long.

MR. WILLIS WHITED: Referring to the open tank process of impregnating timber, I got the impression some where that the fumes are almost fatal, at least very injurious to men working around it.

MR. G. B. SHIPLEY: I think you are mistaken, because it seems to benefit people working around the plant. You will

* Deputy County Engineer for Allegheny County, Pittsburgh.

find it very difficult though in breathing the hot fumes. In treating, the creosote is forced into the wood under high temperatures and upon opening cylinder doors, the hot fumes blow out from the cylinders and vaporize, usually saturating the operator's clothes and everything else, but it is not injurious to the health. If creosote oil contains acids, then it will slightly burn your face.

MR. V. R. COVELL: In the issue of "Engineering-Contracting" of October 19, 1910, a specification for Creosoted Wood Block Pavement fixes the specific gravity of the oil at 1.10 for 38 deg. cent. This is heavier than is usually specified and there seems to be quite a variance of opinion as to the desirable figure to specify. What is your judgment on this point;

MR. G. B. SHIPLEY: I am unable to pass on that. However, the article was probably written for the specifications of wood block treatment, and is supposed to be a creosote that has a greater specific gravity than that used in the treatment of ties and timbers. I figure that specific gravity runs from 1.04 to 1.07. In other words, you get an oil that will weigh about 8.75 lb. to the gallon, whereas 1.10 would weigh over 9 lb. to the gallon. I believe that must have been for wood block specifications.

MR. V. R. COVELL: What effect does the increase or decrease of specific gravity have on the quality of the product? In the discussion of the paper, "A Review of Chicago Paving Practice," in Vol. LXVI, of the Transactions of the American Society of Civil Engineers, a quotation from Captain John C. Oakes, U. S. A. is as follows: "An oil having a specific gravity as a whole of more than 1.07, should be looked on with suspicion and investigated. Unless it is almost wholly lacking in low-boiling fractions, it possibly has some hard pitch or undistilled coal-tar mixed with it."

MR. G. B. SHIPLEY: Some persons claim it contains a higher percentage of solids, and if I am not mistaken, it does contain as much antiseptic qualities as the creosote containing

about 1.04 to 1.07. It takes a higher pressure and a higher temperature to penetrate the wood.

MR. N. S. SPRAGUE*: The question raised by Mr. Covell about the specific gravity of creosote oil for the treatment of wood block pavements was very thoroughly discussed at a convention of municipal engineers held in Chicago about a year ago, for the purpose of standardizing paving specifications. The committee charged with the preparation of specifications for creosoted wood block pavements held a conference with representatives of some of the creosoting companies and listened to their side of the argument relative to the proper value of the specific gravity of this creosote oil. The question was given very careful consideration and this committee had the assistance and advice of some of the best chemists that could be obtained, and after a very careful review of the data, recommended a specific gravity for this creosote oil of 1.10.

During the past year this committee, of which the writer is a member, has been subjected to considerable criticism by certain companies and individuals on account of the limiting value of the specific gravity of the creosote oil adopted by this convention. Certain of the companies in this country engaged in the treatment of wood block for pavements alleged that creosote oil having a specific gravity of 1.10 could not be obtained except from one corporation, in other words, the product was controlled by one company.

The American Society of Municipal Improvements recently appointed a committee to prepare standard specifications for creosoted wood block pavements. As the time allowed this committee for the preparation of a report was so limited the committee decided to adopt tentatively the Chicago specifications with some slight modifications. This committee felt, in view of the recent criticism, that the matter of the value assigned to the specific gravity of the creosote oil should be investigated, with a view of determining whether or not the statements made by certain of the creosoting companies, to the effect that the product was controlled by one company, was true.

* Superintendent, Bureau of Construction, Dept. of Public Works, City of Pittsburgh.

Mr. A. W. Dow, of the firm of Dow & Smith, of New York, a member of the American Institute of Chemical Engineers, and Chairman of this committee reported, after making many searching inquiries, that creosote oil having a specific gravity of 1.10 could be obtained by any one having the necessary capital. As this part of the report was left in the hands of the Chairman of the committee I personally did not inquire into the matter and endorsed the report of the committee. Today I received a letter from the Wyckoff Pipe and Creosoting Company, asking me for information as to where they could obtain 200 000 gallons of creosote oil having a specific gravity of 1.10.

In view of the foregoing, it appears that the question relating to the proper value of the specific gravity of creosote oil for the treatment of wood block pavements is worthy of further consideration.

In my opinion, the quantity of preservative treatment for timber should be determined by the character of the wood to be treated and the uses for which it is intended. For example, in the case of wood block pavements the quantity of preservative used should be determined by the amount of traffic to which the pavement would be subjected, rather than by an arbitrary fixed amount. The wood block pavement subjected to heavy traffic requires a less amount of preservative than a wood block pavement laid on a residence street or alley where the traffic is light and is used for only local needs. The treated block in the first instance will wear out before it will rot out, while in the latter case the wood will decay before it wears out, and therefore a larger percentage of preservative should be used in treating the wood.

With respect to the quantity of treatment for railroad ties and lumber used for structural purposes, it appears that a preservative treatment of ten to twelve pounds of oil per cubic foot prolongs the life of this material several years. Would it not be economy to use a larger percentage of preservative at a relatively small additional cost and thus prolong the life of the wood a few years more?

Mr. Albert Kingsbury*: I was concerned in the installation of a steam plant in 1892 which included underground steam pipes connecting a system of buildings for heating purposes. The pipes were placed underground in wooden boxes, and the man holes and manhole covers, placed at intervals along the steam lines, were also made of wood. This wood was treated by what was called at that time the Kyanizing process, which I understood to be a mercuric chloride treatment. The wood was second growth white pine of a rather poor grade with a good many knots and some sap wood. The variety of conditions under which the wood was used gave as wide a range as one could expect to find for testing the effectiveness of the preservative process. There was a good deal of moisture present at all times as the ground waters had pretty free access to the wooden boxes and around the manholes; and the heat from the steam pipes heated the wood to various temperatures from the lowest winter temperature up to the charring point. I had ample opportunity to note the condition of this wood during the first seven years after it was put in and during that time I do not recall having noticed anything in the way of decay. The wood appeared to be somewhat more brittle as a result of the treatment than it otherwise would have been, but aside from that I noticed no deleterious effects of any kind. I have lately learned, however, that all the wood has been replaced by other material, the last being replaced in 1909. The tops of the boxes were not Kyanized, and all these planks rotted out. The bottom planks also rotted, apparently because of the large amount of water which ran along the bottoms at certain seasons, probably dissolving out the mercuric chloride. The sides of the boxes were fairly well preserved.

Mr. N. S. Sprague: In the treatment of piles, where from sixteen to twenty-four pounds of creosote oil is used, have you ever had any trouble or complaint due to the oozing out of the oil after the piles have been in service. Wood block pavements have caused serious trouble due to the oozing out of the pre-

* Consulting Engineer, Pittsburgh.

servatives after the pavements have been laid, requiring the application of hot sand and a thorough scraping and cleaning.

Mr. G. B. Shipley: In treating the piling it is customary to season or steam the material, and if the vacuum fails to take out all the water there is a tendency, in forcing in the creosote, to meet resistance which results after driving in the water with some creosote oozing out through the center of the timber and the top showing that material was not properly treated.

Mr. V. R. Covell: Is it more economical to treat Southern timber in the North? Thus far the timber furnished, under contract for the repair of County Bridges, has been treated in the South; and is it not difficult to determine accurately the weight of oil per cubic foot that is forced into the timber?

Mr. G. B. Shipley: Answering the last question first, no it is not. The question of where is the best place to have the material treated I think resolves itself into the question of transportation. If you go South for timber and ship North for treatment, you could save considerable on freight. For instance, if you are treating 16 lb. to cubic foot, you will save 16 lb. per cubic foot in freight which means considerable on long distance transportation.

The question of determining how much oil per cubic foot is in the treated material depends on the honesty of the operator. You can put a certain amount of oil in certain timber and by carefully manipulating your treatment you can get your oil into the wood, providing you know in the first place how much that wood will take. But the best way to determine how much oil is in the wood is to first of all weigh your material as it goes into the cylinder, then weigh the oil as it is forced into the wood, and afterwards weigh your material as it goes out of the cylinder. In that way you will have two checks; you will have a check on the amount of oil you put in as it goes in with the force pump, and then also as it is finally weighed after treatment. There is going to be a slight variation, but it should not be over 5 per cent.

MR. V. R. COVELL: That would not be true unless the timber was seasoned. If one had green timber he could not tell.

MR. G. B. SHIPLEY: Yes, the only way is to measure or weigh the creosote as used or forced into wood. If you measure the creosote, you must compute for temperature, for creosote oil will expand and contract about one percent for each 22 degrees difference in temperature.

MR. H. R. BLICKLE*: I would like to ask about the block pavement. One wood absorbs more oil than another. Loblolly pine absorbs more than the other hard woods. Would that not, therefore, be a better material to use for pavement than long leaf, though not quite as hard as long leaf? The oil being almost as essential in block pavement of streets as wearing quality in order to counteract the chemical action of foreign substances.

MR. G. B. SHIPLEY: It is not as hard. Long leaf yellow pine is a better wearing wood.

MR. H. R. BLICKLE: Isn't it a fact that most of the blocks are loblolly pine?

MR. G. B. SHIPLEY: Well I don't know about that.

R. A. CUMMINGS†: Some time ago, while in New Orleans, I noticed that many of the electric light poles which had been treated, decayed badly at the top while the remaining portion of the poles, down to the ground level, appeared to be perfectly sound. As this condition appeared to obtain quite generally throughout the city, I am led to inquire why this excessive decay should appear at the top of the poles only?

CORRESPONDENCE

MR. F. M. BOND‡: The Secretary, Mr. Elmer K. Hiles, has kindly suggested that some remarks by the Forest Products Laboratory would be welcomed by the Society upon points brought up in the discussion of Mr. Winslow's paper. In the

* Chief Engineer, Fort Pitt Bridge Works, Pittsburgh.

† Consulting Engineer, Pittsburgh.

‡ Engineer in Charge, Forest Products Laboratory, U. S. Forest Service, Madison, Wis.

absence of Mr. Winslow from the Laboratory, the writer has, therefore, carefully read over the discussion and begs to offer a few suggestions upon the points raised in the discussion which it is hoped will be of interest to the Society.

In regard to the relatively high treatment pressures: It is hardly probable that any pressure that may be obtained in a treating cylinder could of itself break down the cells of seasoned or unseasoned wood. As has been already pointed out in Mr. Winslow's paper, when timber is properly seasoned, either in the open air or by the ordinary artificial means, the cells have been found to develop slits through which air or liquid may pass. It would, therefore, seem that there is little chance of any marked difference in pressure existing within the structure of properly conditioned wood. In the case of green wood, if consideration is taken of the fact that the compressive strength of green wood varies roughly from 3 000 to 5 000 lb. per sq. in., based upon the total area, including air spaces, etc., that its tensile strength is even greater and that the actual wood fiber is only a part of this area, it will be at once seen that the actual strength of wood fiber must far exceed the strength necessary to withstand any pressure that might be obtained in a treating cylinder. Further, the following quotation from Bulletin No. 107 of the American Railway Engineering and Maintenance of Way Association, page 103, is submitted:

> "The tracheids with these peculiar valve-like pits are apparently capable of withstanding an enormous pressure. In the living cells, the pressures due to osmosis frequently amount to three or four atmospheres, and it is stated by Strassburger that a pressure as high as eight atmospheres (120 lb. gauge) have been measured. Livingston states that the pressure may vary from two to more than a hundred atmospheres (1500 lb. gauge) within living cells."*

It would appear, therefore, that the breaking down of the wood structure, when high pressure has been used, was due to some other cause than the pressure itself; without specific details, it would be impossible to assign the exact cause.

* From a paper by Mr. Harry Donald Tiemann, Engineer in Timber Testing, Forest Service.

Relatively high specific gravity in coal-tar creosote is ordinarily obtained either by distilling off some of the lighter fractions or by the addition of pitch. The former method produces a creosote which is generally regarded as of superior quality, since it contains an increased proportion of the higher boiling or anthracene oils, and these fractions are generally believed to have a high antiseptic value. It has been found by analysis of treated wood that the lower boiling fractions, although they may be good antiseptics, remain in the wood but a short time on account of their high volatility when placed in the open air, and their low specific gravity and low viscosity when the timber is submerged. By boiling off the low fractions, however, the specific gravity of creosote can not be raised higher than about 1.08.

When the specific gravity of creosote is raised by the addition of pitch, its viscosity is increased so that higher temperatures are necessary in order to force the creosote into the timber. Moreover, pitch contains considerable free carbon which plugs up the outer spaces in the wood and retards the penetration of the preservative. It has also been found that pitch, even after the removal of the free carbon, can not be forced much beyond the surface of the wood.

Treatment of paving blocks with creosote has for one of its objects, besides preserving the wood, the filling up of the wood structure with creosote to a large degree in order to reduce the amount of water that can be subsequently absorbed by the block. In this manner the expansion of the blocks is reduced considerably. Experiments by Dr. W. K. Hatt, of Purdue University, show that birch and larch paving blocks, treated with from 20 to 22 pounds of creosote per cubic foot, had their expansion due to the taking up of water reduced 50 percent in comparison with untreated blocks of these same species. From this consideration, therefore, it appears unwise to reduce the amount of creosote ordinarily injected into paving blocks even when the pavement would be subjected to excessive wear under heavy traffic.

In regard to whether it would be more economical to use

heavier treatments for railway ties than from 10 to 12 pounds per cubic foot: There is a large amount of data on treatments using this amount of creosote. These data show that where the treatments were properly applied, the amount of creosote was sufficient to preserve the ties for a period at least equaling their mechanical life. The tendency at the present time is to reduce this amount even with full-cell treatments; 8 to 10 pounds per cubic foot being the common practice.

The failure of the Kyanized pipe conduit, as described by a member of the Society, was undoubtedly due to the leaching out of mercuric-chloride by the running water in the bottom of the trench. The use of mercuric-chloride, zinc-chloride and other antiseptic salts is confined almost entirely to timber placed in relatively dry positions, on account of the leaching action of water. Zinz-chloride is, however, often used for timbers placed in damp parts of mines where only a limited life of the timber is required and when this required life exceeds the natural life. Creosote would be the proper preservative to use in a pipe conduit because of its insolubility in water and its high antiseptic quality.

Pitch is the only constituent of creosote which oozes out of treated timber to any great extent. The reason for this is that pitch does not penetrate beyond the outermost fibers of the wood due to its high viscosity and the free carbon usually contained in it. In paving blocks, where a high specific gravity is specified and this is obtained by the addition of pitch, the oozing out is usually considerable.

In regard to the use of loblolly pine for creosoted paving blocks: Since the blocks used in this country are usually four inches in depth and since practically any species of wood ordinarily used for this purpose may be thoroughly impregnated for this short distance by end penetration, the ease with which loblolly pine subjects itself to treatment would not increase its value as a paving block. Because of the short mechanical life of loblolly pine, its use as a paving material is not considered economical. A very similar species of wood has been used for this purpose in Paris, but it is said to have shown excessive wear,

although a layer of coarse gravel was laid on the blocks and this became imbedded in the surface by the action of the traffic, thus increasing the wearing qualities of the pavement. In this country the use of longleaf pine, Norway pine and other hard conifers seems to be the most usual practice.

In the absence of specific data on the species, the treatment, etc., of the electric light poles whose tops have been found to show decay in New Orleans, it is impossible to assign a cause for this. Assuming that the poles were properly treated with a good coal-tar creosote and that they were previously properly conditioned, it seems that rot at the top of the pole must have been caused through the exposure of the interior part of the pole beyond the layer of treated wood. If the holes for the cross-arm bolts were bored after the poles were treated or if the tops of the poles were cut off after treatment in order to make them of proper length, this would have given the fungous growth a sufficiently good means of entrance to cause decay. The top of the pole would be the most favorable of the upper part of the pole for decay to start, because, on account of its position, it is subjected to having lodged on it a greater number of spores of the wood-destroying fungi which are always present in the air. The top is also the part most exposed to the action of the weather.

The Forest Products Laboratory wishes to express its appreciation of the kind remarks by Mr. Shipley concerning its wood preservation equipment. Since a brief description of the apparatus and some of the experiments that are now being conducted in the laboratory may be of interest, the writer takes this opportunity of bringing this to the attention of the Society.

The laboratory has installed the following independent and complete equipments:

One cylinder 3 ft. 6 in. in diameter by 12 ft. long; maximum working pressure 300 lb. per sq. in.;

One cylinder 18 in. in diameter by 4 ft. long; maximum working pressure 600 lb. per sq. in.;

One cylinder 12 in. in diameter by 24 in. long coupled with one cylinder 8 in. in diameter by 18 in. long; maxi-

mum working pressure 300 lb. per. sq. in.;

Two open tanks 4 ft. by 12 ft. by 4 ft. deep for absorption treatments;

One underground fungus pit 11 ft. by 21 ft. by 8 ft. deep.

All of the pressure cylinders are equipped with steam coils or jackets, measuring tanks, pressure pumps, compressed air, vacuum and live steam connections. The large cylinder has, in addition to the above equipment, two receiving tanks, one treating car, platform scales for weighing the charge before and after treatment and a centrifugal pump for keeping up a circulation when emulsions are used in the cylinder.

The fungus pit is divided into compartments which are kept under what is believed to be the most desirable conditions of light, heat and humidity for fungous growth. This pit is under the care of a pathologist detailed to the Forest Products Laboratory from the Bureau of Plant Industry. Specimens to be placed in the pit are first sterilized and then inoculated with fungi.

By means of the fungus pit it is expected to force the growth of fungi in wood and in this manner obtain accelerated results. While such results may not be in all respects comparable to regular service tests they should at least give indication of the comparative value of different treatments and preservatives.

Some of the experiments now being conducted at the laboratory which would be of especial interest to the Society are:

An experiment in which five sets of specimens have been treated each by one of the five principal fractions of a good coal-tar creosote and are to be subjected to the action of marine borers in San Francisco Bay and in the Gulf of Mexico. Other specimens of somewhat different form but treated in the same manner are to be subjected to the action of fungous growth in the rotting pit. By this means it is hoped to ascertain some indication of which fractions of creosote offer the greatest resistance to decay and to marine borers.

Another interesting experiment which is now being carried on in co-operation with the Chicago, Milwaukee and St.

Paul Railroad is the treatment of 100 ties, each of red oak and also the same number each of hard maple by a number of preservatives and different treatments, and subsequently placing these ties in the tracks of the railroad for a service test. Complete data are being taken on the peculiarities of each individual tie and its treatment. Sections are also being taken of one tie from each treatment and these sections will be subjected to fungous attack in the rotting pit.

With these brief remarks, the Forest Products Laboratory wishes to extend to all of the members of the Society a cordial invitation to visit the laboratory, where they will be shown every courtesy and attention, and will be given every facility for inspecting the equipment.

THE ELECTRIC FURNACE:

ITS PLACE IN SIDERURGY

By P. McNiven Bennie*.

What the Steel Industry owes to Electric Furnaces: As out of the "Iron Age" came the "Steel Age" so the "Age of Steel" begat the "Age of Alloys."

It needs but a moment's consideration to realize the extensive use made of alloys nowadays. For almost every ill that steel is heir to, the metallurgist seeks an alloy as cure or palliative. But few realize to what extent metallurgy is beholden to its younger sister electrometallurgy for the existence of an imposing list of extremely useful metals and alloys.

There is hardly need before a Society of this character to enumerate the list, but a few references will serve to illustrate:

Aluminum, the product of an electrometallurgical process (and by way, the result of Pittsburgh enterprise) finds extensive use among steel makers. The alumino-thermic process, of such great utility, depends upon electrometallurgy for its most important constituent. Metallic calcium, made by the electrolytic method, is finding new uses daily, by reason of its great chemical activity.

Whoever hears now of blast-furnace ferro-silicon? The electric furnace product, containing 25, 50, 75 or 90 per cent silicon, has almost completely superseded it.

That marvelous advance, high speed steel, and alloy steels generally, owe existence to electric furnace products, such as ferro-chromium, ferro-tungsten and tungsten metal.

Then let us not overlook such important products as ferro-titanium, containing 10 per cent titanium, and ferro-vanadium, containing 25 per cent vanadium; each made in electric furnaces. Some extremely useful ternary alloys are now coming into favor,

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* Consulting Electro-chemical Engineer, Fitzgerald & Bennie, Niagara Falls, N. Y.

as ferro-nickel-chromium, containing nickel 30 per cent and chromium 50 per cent; also ferro-silicon-chromium, having silicon 8 to 10 per cent and chromium 50 per cent. Another interesting alloy is alumino-silico manganese, of the composition: aluminum 20 per cent, silicon 35 per cent and manganese 40 per cent. The old system is represented by a single, and still vigorous survivor, ferro-manganese.

It is but a few brief years since these alloys made their appearance as articles of commerce, and it is safe to say that a few years hence will see most of them firmly entrenched as indispensable aids to steel-making.

Probably not many of you are aware that as far back as 1895 an electric furnace was in regular use in Pittsburgh for making ferro-chromium for special purposes. That was before the development of the present alloy industry on the large scale at Niagara Falls, and elsewhere, using hydro-electric power.

Thus does siderurgy already owe a considerable debt to the electric furnace. Additional obligations now being incurred will be treated in other portions of this paper.

Electric Furnace Production of Pig Iron: While in localities where favorable conditions exist, the electric furnace has been developing rapidly for the production of various alloys, other lines of manufacture have not been neglected.

This meeting is held in the heart of one of the world's great pig iron centers. This localizing of an industry has not been by mere chance; the causes therefor can be definitely traced. Briefly put the Pittsburgh district presented conditions favorable to the making and marketing of iron and steel products.

So it is with the problem of producing pig iron by means of the electric furnace. Certain conditions are absolutely essential to success, and those conditions can be found in some localities at the present day.

Cheap electric power is a prime requisite, but really cheap electric power, when considered for pig iron making, can only be produced by hydro-electric installations. Such installations are still but a thing of yesterday.

The development of an electric furnace pig iron industry

has also been hampered by the lack of a suitable furnace, fit for prolonged campaigns; able to withstand rough usage, and sometimes even abuse. It is only recently that such apparatus has been developed.

Fig. 1. Magnetite and Calcite Contact in California.

To-day it gives me pleasure to announce that the commercial production of pig iron of high quality by means of the electric furnace is an accomplished fact; that apparatus satisfactory for the purpose exists, and has demonstrated its ability to meet the demands upon it; that the cost figures show a commercial proposition. Of the two principal enterprises now developed, one is at Domnarfvet, Sweden, and the other in Shasta County, California. The latter installation, worked out by Mr. D. A. Lyon of the Noble Electric Steel Co., seems to be the more advanced of the two, and will be described here.

The Noble Electric Steel Company has put down a complete plant, including equipment for mining and handling iron

ore and limestone; a complete by-product recovery charcoal plant, and a large electric furnace, the power for which is supplied from the generating stations of the Northern California Power Co.

The local conditions at the California plant are particularly good. The furnace plant is located on the Pitt River with reference to the continguity of iron ore and limestone. Immediately to the rear of the furnace building is a mountain about 1800 ft. high. At its summit is a large deposit of high grade magnetite, averaging 68 per cent. iron and very low in sulphur and phosphorus. In contact with the iron ore is a body of calcite of very good quality. The two adjoining deposits are shown in Fig. 1. The method of assembling these two important items, therefore, becomes very simple. For sometime to come all the iron ore the furnaces can use will be produced from an open quarry. The materials are conveyed by surface tramway to a point on the face of the mountain above the furnace buildings; there crushed by motor-driven appliances, then dropped by gravity tram into bins adjacent to the electric furnace. The iron ore can be laid down at $1.50 the ton, while the source of lime should not cost over 50 cents the ton.

For reducing carbon, charcoal will be used. The installation includes a complete by-product recovery charcoal plant, the supply of wood for which is supplied by local lumber companies at a figure that should permit of $9.00 charcoal. Electric power being supplied by the Northern California Power Co., an affiliated concern, the actual price charged for power is a matter of mutual agreement, but about $15.00 the horse-power year is an approximate figure. The charcoal consumption should be in the neighborhood of one-third ton per ton of pig produced. Such a plant should produce a very high grade iron at a cost of between $15.00 and $16.00 the ton.

The California furnace is shown in sectional elevation in Fig. 2. The base of the furnace is composed of a steel shell lined with suitable refractory materials, forming a circular crucible. Above the crucible thus formed is a superposed stack, somewhat resembling a small blast furnace in shape, and having a bosh communicating with the crucible.

The method of working is as follows: The charge, consisting of iron ore, mixed with its proper proportion of fluxing materials, is fed into a pre-heating chamber (*b*) wherein these constituents are dried and heated by means of gases from the chamber (*k*) at the top of the stack. The gases pass by the flue (*e*) to the heating chamber (*b*) and out by flue (*f*). A damper (*d*) permits of direct passage to atmosphere when desired.

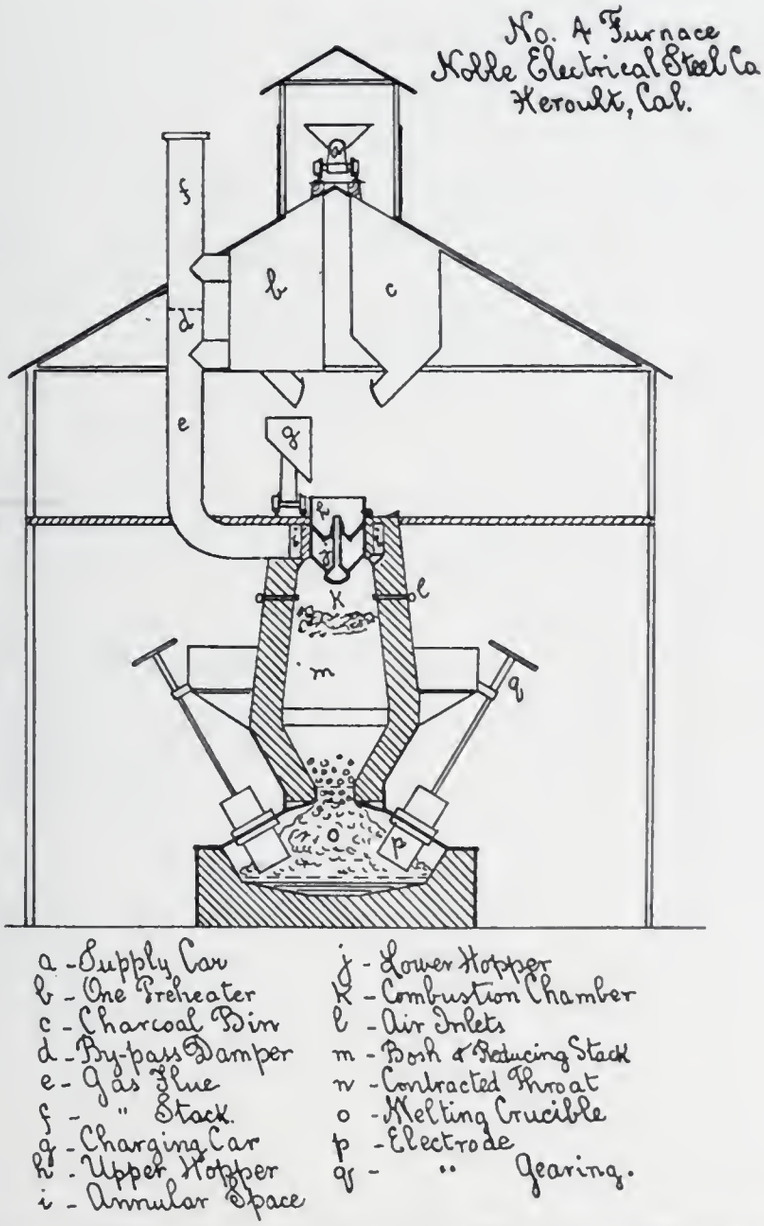

Fig. 2. Sectional Elevation of Electric Pig Iron Furnace, California.

Carbon, in the form of charcoal, is contained in hopper (*c*) and fed alternately with the iron ore and lime mixture by means of scale car (*g*) running on a circular track around the double-bell hopper (*h*).

The furnace itself, shown in Fig. 3, is designed to have a daily capacity of 20 to 25 tons of pig iron. Electrically it is designed for a maximum load of 1500 kilowatts, 3-phase current at 60 cycles, 100 volts, being supplied from three 750 k. w. transformers. There are six electrodes employed, two on each phase. Three of these electrodes may be seen in position in the illustration, the furnace not being completed at the time the photograph was taken. Three tapholes have been provided at different levels, so that if necessary the crucible of the furnace may be partially or completely emptied.

In consequence of its situation at a considerable distance from the source of necessary supplies, such as electrodes, electrical machinery, refractories, etc., some delays have been experienced in the construction and operation of this plant. However, December, 1909, saw the beginning of a serious campaign which continued until shut down by an excessively dry summer, resulting in the failure of the supply of power. This defect is to be remedied for the future.

While running this furnace produced about 20 tons of pig iron daily. We are informed that the power consumption will not average over 0.25 e. h. p. year per ton. This is a better production than has been shown by the Swedish installation.

That a very good grade of pig iron is produced may be seen from the following analysis of products:

ANALYSIS OF ELECTRIC FURNACE PIG IRON.

	1	2	3	4
Silicon	0.940	0.840	0.980	0.940
Sulphur	0.042	0.037	0.049	0.002
Phosphorus	0.027	0.022	0.030	0.020
Manganese	0.110	0.030	0.080	trace
Combined Carbon	1.200	——	4.560	3.250
Graphite Carbon	2.060	——		

These figures indicate an iron of exceptional quality, but the high purity of the ores used should be considered. However, owing to the peculiar conditions of its production, it may well be that electric furnace pig iron will create a special market for itself.

The Noble Electric Steel Co. is now building two additional

furnaces, while a sufficient number is contemplated during the coming year to bring the total production up to 100 tons daily.

It is the intention to turn some of the pig iron into steel. Obviously iron of such purity would be particularly fit for Bessemer treatment. But it may be decided to do it electrically thus avoiding the introduction of nitrogen altogether.

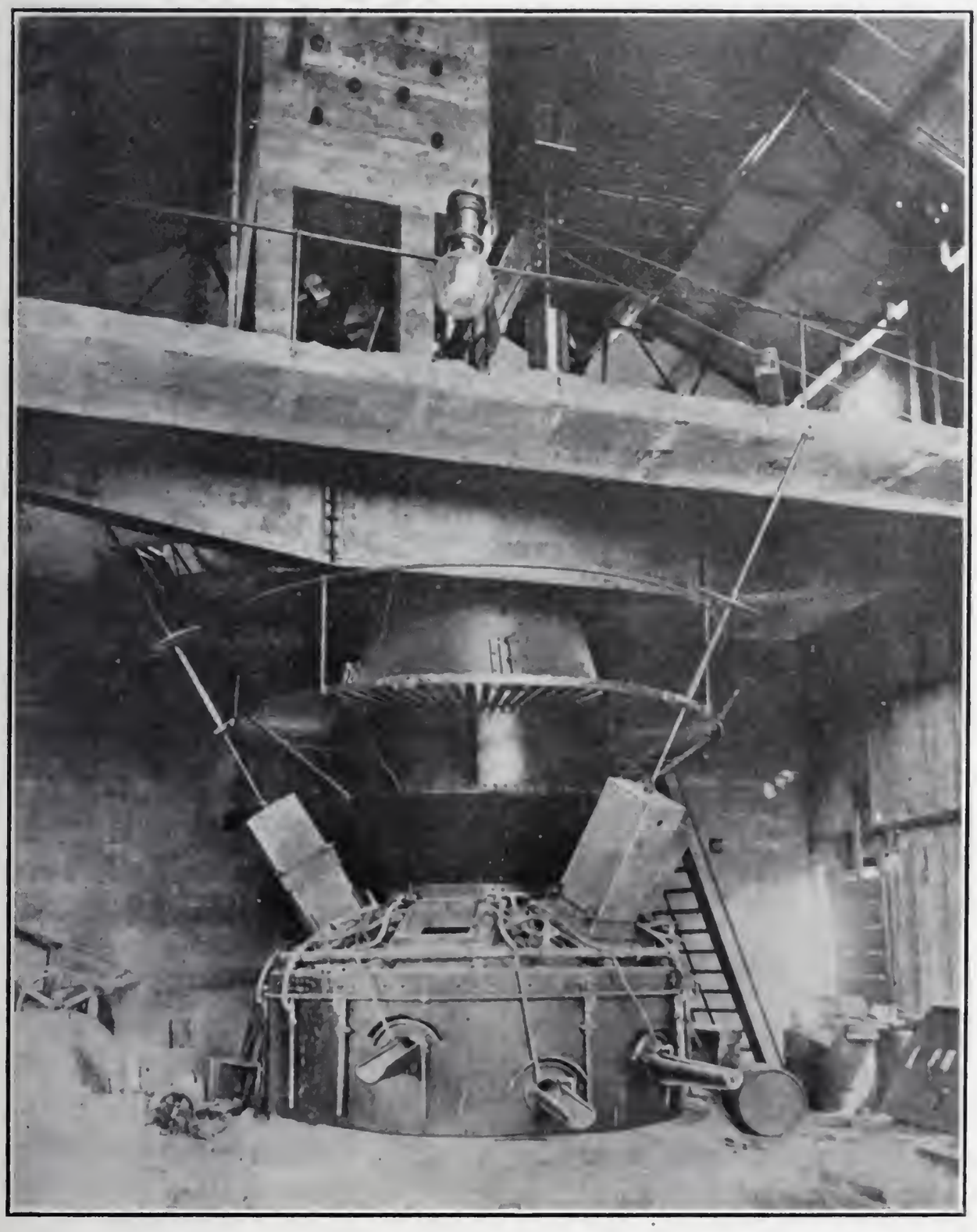

Fig. 3. Photograph of California Pig Iron Furnace.

The Swedish installation, using a furnace designed by Messrs. Gronwall, Stalhane and Lindblad, is curiously similar to the California furnace, except that three instead of six electrodes are used. With electric power at the low rate of $9.65 the h. p. year, it is calculated that pig iron can be produced for about $14.25 the ton.

Thus, while the electric furnace for pig iron is in actual existence, it contains no menace to the blast furnace; nor is there likelihood of the establishment of such installations within the borders of the Keystone State.

Uses of Electric Furnaces in Steel Production: The steel industry has become so highly specialized, covering such a wide range of manufacture, and multifarious uses for the products, that it is not possible to thoroughly cover the field in a single evening, except in a very condensed manner. It is perhaps of more interest to show the types which are finding commercial application at the present day, than to trace the history of their development.

For this purpose electric steel furnaces may be divided into three general classes, as follows:

A. Electric furnaces using electrodes, with an open arc, and heating by radiation. To this class belongs the furnace developed by Stassano.

B. Electric furnaces using electrodes which dip into the slag or bath; or where an arc is sometimes formed between the electrode and the bath. To this class belong the types developed by Girod, Heroult and Keller.

C. Electric induction furnaces, where the bath forms the secondary of a transformer, the secondary thus consisting of a closed circuit having but a single turn. To this type belong the furnaces of Colby, Kjellin and the modified furnaces of Rochling-Rodenhauser.

The Stassano Furnace: The illustration shown in Fig. 4 is a diagram of the furnace developed by Major Ernesto Stassano, and as applied at the Government Artillery Arsenal, at Turin, Italy. In this type of furnace electric energy is converted into heat energy by means of the voltaic arc formed between carbon electrodes, at a short distance above the maximum level of the bath. Heat is transmitted by radiation into the material under treatment.

The working chamber consists of a circular cavity, lined with suitable refractory material, and having a flat bottom forming the hearth.

The furnace is shown as slightly inclined from the vertical, Stassano's practice being to slowly rotate the furnace body with the idea of producing a certain mixing effect and bringing the material to temperature as soon as possible. The efficacy of the method seems doubtful, however.

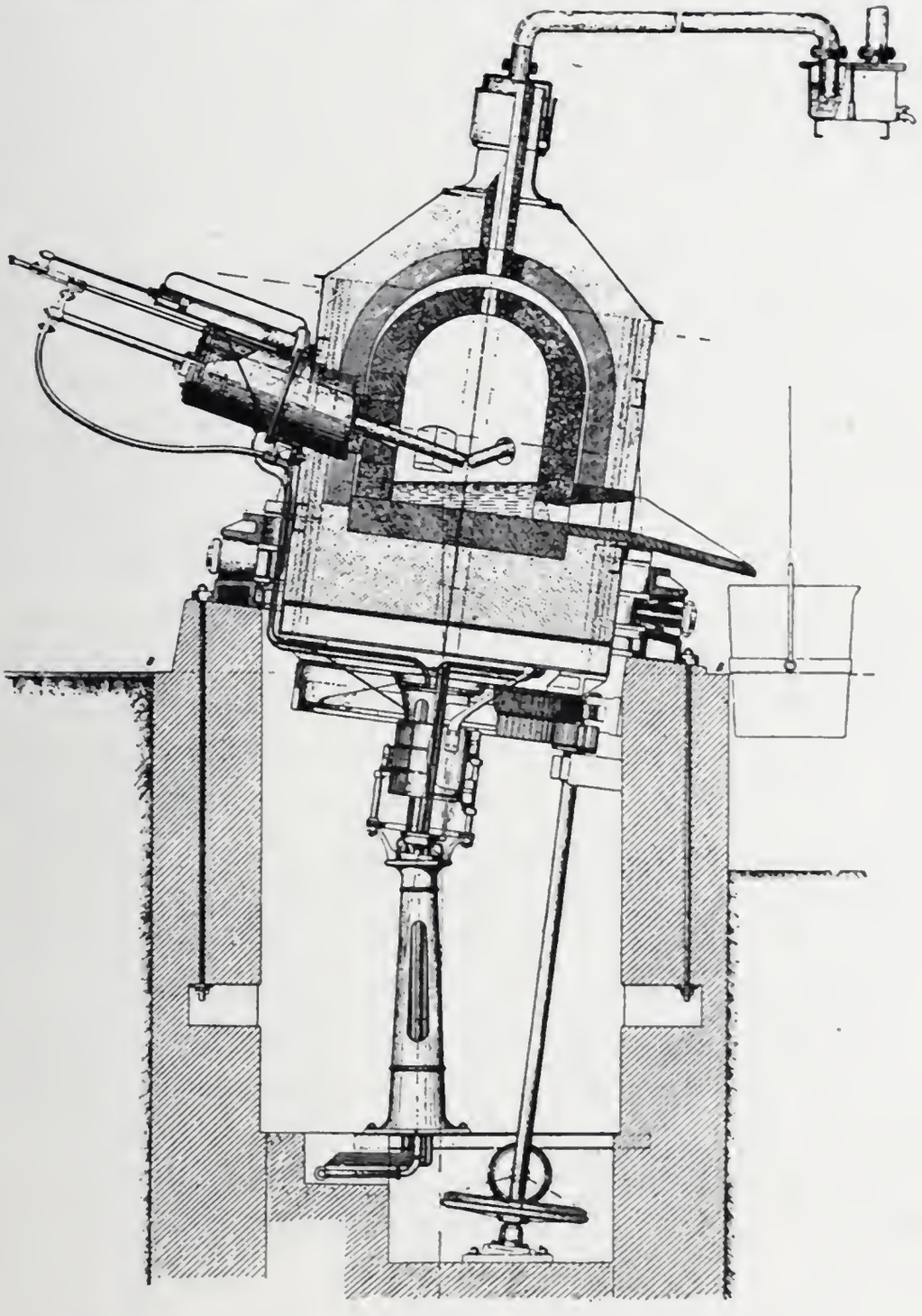

Fig. 4. Vertical Section of Stassano Furnace.

A distinguishing characteristic of this furnace is the existence of a really neutral atmosphere within the working chamber, the latter being hermetically sealed when working. This is reflected in the low electrode consumption, which is in the neighborhood of 20 to 25 pounds per metric ton of product. The use of fairly small electrodes becomes possible, a current density of 20 amperes per square centimeter, equivalent to 129 amperes per square inch, being used.

The regulation of energy flow becomes a very simple matter with this type of furnace, as it is almost arc-lamp regulation. The arc is out of contact with either slags or metal bath, hence there are no violent fluctuations in resistance, and consequently in energy flow, as is generally the case with furnaces of the electrode type. In the latter types this is particularly noticeable when starting with charges of cold scrap metal.

On the other hand, the power consumption in the Stassano type is somewhat higher than in other types, being about 1000 kilowatt hours per ton with cold scrap charge, against 600 to 800 kilowatt hours with several other types. Owing to its construction repairs cannot well be made during the running of the furnace; the effective life of the lining is usually about four weeks, the practice being to completely renew the lining at the end of that period.

Aside from the Stassano furnaces installed at the Turin Artillery Arsenal, a number are in use at other works in Europe, notably at Bonner Fraser Fabrik, Bonn-on-the Rhine, Germany. In all, Stassano claims to have ten furnaces now at work.

Starting with ordinary scrap materials, refining can be carried out to any desired degree. Steel of crucible quality can be produced, suitable for fine castings or tool purposes. Stassano has made some very good metal from a mixture of iron ore and carbon, although in this case the energy consumption is somewhat high, as might be expected. A specimen of soft steel made by the direct process, showed the following:

C	0.150	per cent.
Si	0.140	"
S	0.050	"
P	0.036	"
Mn	0.420	"

Stassano claims to be ready to construct furnaces of this type up to 800 kilowatts electrical capacity, sufficient to produce five or six tons of metal to the heat.

As this type of furnace is readily adapted to the use of three-phase alternating currents, in which case three electrodes are used, it fits very well into the usual conditions of modern power supply in manufacturing districts.

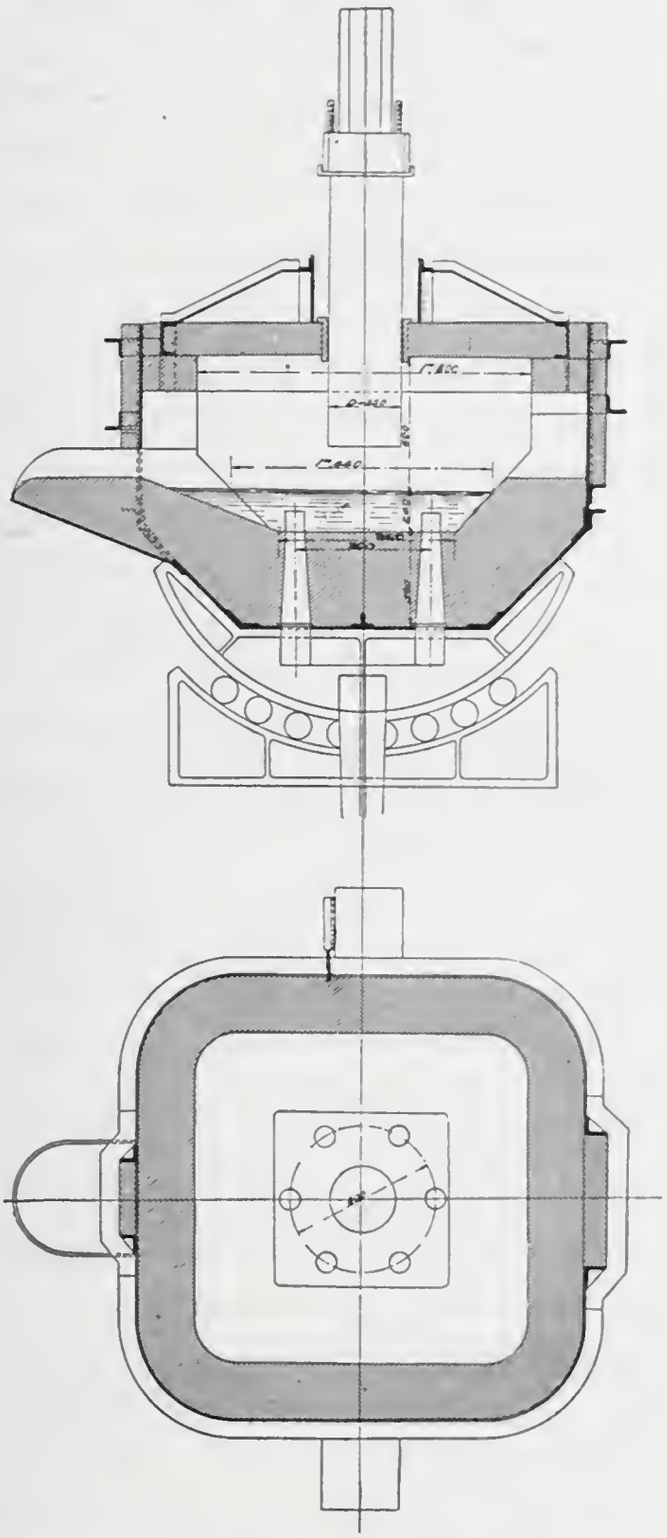

Fig. 5. Sectional Elevation and Plan of Girod Furnace.

The Girod Furnace: Paul Girod, of the Societe Anonyme Electro-metallurgique, Ugine, France, has worked along different lines, and has finally adopted a type of furnace having a conducting bottom, although this principle is not new in furnace construction.

Fig. 5 shows this type in sectional elevation and plan. The furnace body is made of steel plate, lined with basic refractory materials, such as dolomite or magnesite, this forming the working chamber. The cover is lined with silica brick, leaving openings for the passage of the movable upper or working electrodes.

When working, the hearth is filled to a depth of 12 to 14 inches with molten metal. One or several, one in the illustration, carbon electrodes of like polarity are movably suspended above the bath, forming one pole of the circuit; the other pole or terminal is formed by a number of pieces of soft steel distributed around the periphery of the hearth at its lowest part, and buried in the refractory material of the hearth. The path of the current is thus through the electrodes, forming an arc between them and the surface of the bath, thence through the bath itself to the soft steel terminals. In practice these soft steel pole-pieces naturally fuse at a certain depth, which, however, is controlled by water cooling the outer ends of these pieces. When ready the metal is poured by simply tilting the furnace by suitable mechanical means.

The problem of regulating the flow of energy in a furnace of this character is relatively simple; the movable electrodes all being in parallel, there is but one drop of potential to provide for, as against two in the case of furnaces having two electrodes in series. The furnace works at about 55 volts, so that there is but little danger from shocks or short circuits. Such a furnace has been found to have a power factor of 0.88.

Furnaces of this sort have now been working at Ugine for several years, without having developed any particular faults due to this method of construction.

Raw materials, consisting of heteregeneous scrap, are charged into the furnace, and refined to a high-grade steel. It is claimed that very hot, fluid and chemically active slags are ob-

tained, permitting any desired degree of refinement. The materials charged have the following composition:

C	0.400 to 0.500
Si	0.150 to 0.250
Mn	0.500 to 0.700
S	0.060 to 0.090
P	0.080 to 0.100

The finished products made at Ugine are carbon steels, special tool steels, alloy steels, structural steel and steel castings. The following Tables 1, 2 and 3, show the various grades:

No.	Quality	C	Si	Mn	S	P	Cr	Ni	Wo
1	Extra Soft	0.079	0.106	0.205	0.015	0.012			
2	Soft	0.236	0.180	0.431	0.012	0.010			
3	Medium	0.283	0.208	0.430	0.014	0.010			
4	Medium hard	0.388	0.155	0.342	0.011	0.009			
5	Medium hard	0.463	0.204	0.463	0.010	0.016			
6	Hard	0.595	0.198	0.302	0.017	0.005			
7	Nickel 2 pct.	0.076	0.099	0.101	0.014	0.010		2.120	
8	Nickel 3 pct. Soft	0.060	0.123	0.209	0.013	0.007		3.470	
9	Nickel 3 pct. Hard	0.364	0.144	0.435	0.012	0.015		3.410	
10	Nickel 5 pct. Soft	0.134	0.148	0.375	0.016	0.013		5.250	
11	Nickel 5 pct. Medium ..	0.250	0.157	0.414	0.010	0.015		5.080	
12	Nickel Chrome	0.420	0.199	0.500	0.010	0.009	0.770	2.530	

Table No. 1—Grades of Steel Made at Girod's Works.

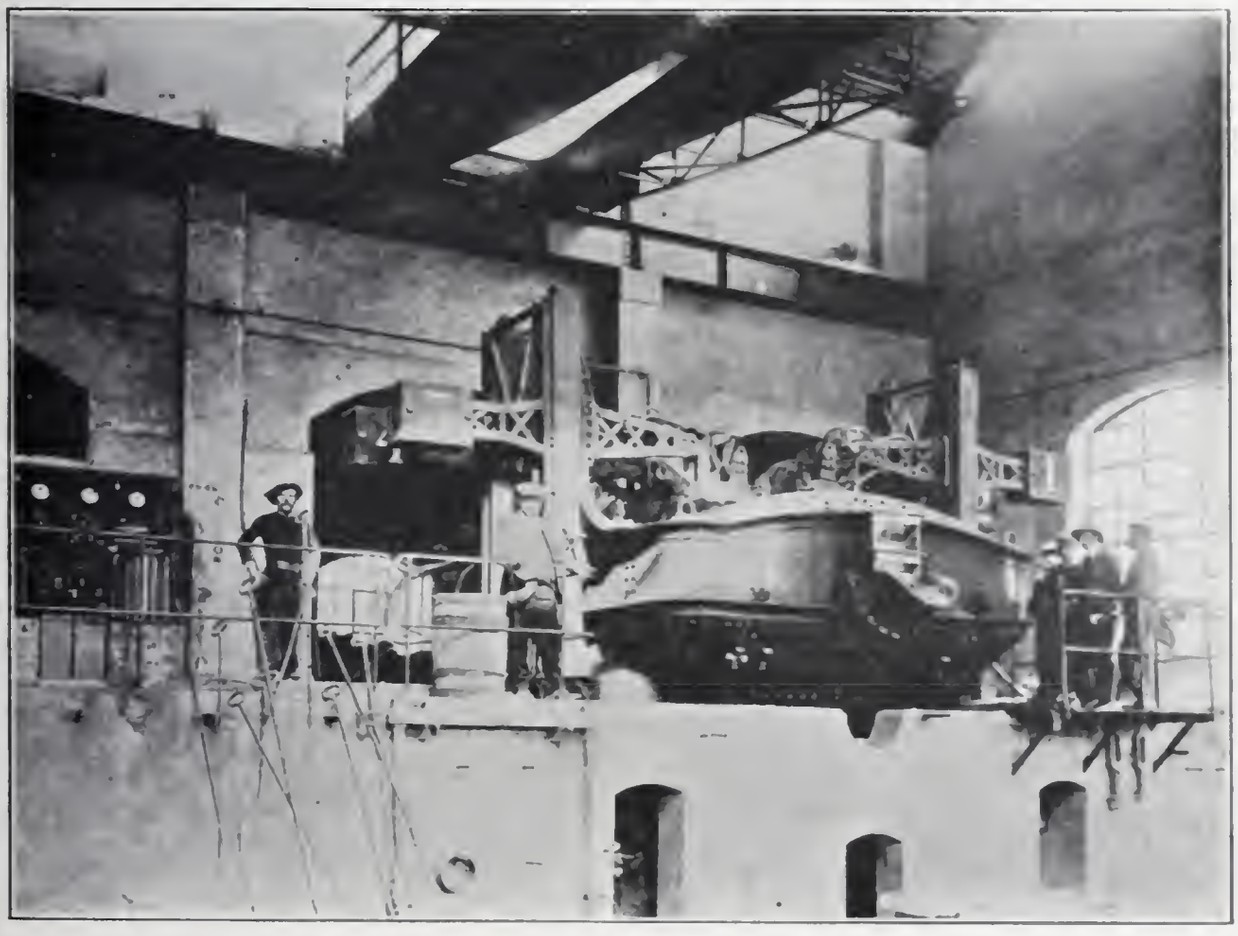

Fig. 6. Twelve Ton Girod Furnace, at Ugine, France.

C	Si	Mn	S	P	Cr	Ni	Wo
1.223	0.168	0.224	0.011	0.010			
1.474	0.119	0.264	0.015	0.007			
1.010	0.219	0.306	0.008	0.009	0.320		
1.277	0.230	0.130	0.009	0.006	0.240		
1.251	0.176	0.258	0.010	0.008	1.210	0.490	
0.689	0.029	0.096	0.012	0.009	6.070	0.460 (Mo)	25.82

Table No. 2—Tool Steels Made at Girod's Works.

No.	Treatment	Elastic Limit lb per sq. in.	Tensile Strength lb per sq. in.	Elongation percent	Contraction percent	Resilience ft. lb. per sq. in.
1	Annealed at 900° C.	40 700	54 800	31.5	70.5	2240
1	Hardened at 850° C.					
	Tempered at 450° C.	48 200	62 700	29.0	80.0	2330
2	Annealed at 900° C.	51 100	72 400	24.5	60.0	1680
2	Hardened at 850° C.					
	Tempered at 450° C.	65 700	97 200	17.0	74.0	1490
3	Annealed at 900° C.	49 000	79 500	20.5	56.0	1420
3	Hardened at 900° C.					
	Tempered at 450° C.	93 700	114 300	15.0	61.0	1300
4	Annealed at 900° C.	58 200	88 000	10.0	51.0	745
4	Hardened at 900° C.					
	Tempered at 450° C.	95 800	113 600	13.5	57.0	725
5	Annealed at 900° C.	72 400	107 900	16.5	41.0	515
5	Oil hard at 900° C.					
	Tempered at 450° C.	123 500	140 400	11.0	46.0	605
6	Annealed at 900° C.	69 600	121 400	12.5	16.5	490
6	Oil hard at 900° C.					
	Tempered at 450° C.	103 700	142 700	10.0	35.7	560
7	Annealed at 850° C.	44 000	58 900	29.0	69.0	1865
7	Hardened at 850° C.					
	Tempered at 450° C.	54 600	67 000	26.0	75.0	2050
8	Annealed at 850° C.	46 100	61 000	29.0	69.0	1515
8	Hardened at 850° C.					
	Tempered at 450° C.	70 000	80 900	20.0	72.0	1305
9	Annealed at 850° C.	72 400	92 300	18.5	45.0	675
10	Annealed at 850° C. Buried in lime	55 380	72 400	23.5	63.0	1775
10	Hardened at 850° C.					
	Tempered at 450° C.	102 200	106 500	12.5	64.0	1820
11	Annealed at 850° C. Air cooled	95 100	105 000	13.5	55.0	1305
12	Annealed at 800° C.	100 800	123 500	10.0	41.0	700
12	Oil hard at 825° C.					
	Tempered at 450° C.	152 000	160 500	12.5	60.0	980

Table No. 3—Mechanical Tests of Steel Made in Girod's Electric Furnace.

NOTE: The tensile tests were made upon test pieces 13.8 mm diameter (0.54 inches) and 4 inches between marks.

TRANSLATOR'S NOTE: The resilience test, resistance to shock, or toughness, is given in kilogrammeters per square centimeter, determined with a Guillery falling weight apparatus upon bars 10 mm square section, with a nick 2 mm wide and 2 mm deep. We have transposed this into foot pounds per square inch.

This type of furnace lends itself very well to melting cold scrap, in which case the energy consumption varies between 900 k. w. hours per ton in the two-ton size, to 700 k. w. hours in the larger furnaces holding 8 to 12 tons per heat. These figures include the melting, refining and finishing, the energy consumption naturally being a function of the initial and final composition of the metal. The consumption of electrodes will also vary as the time, but is given as between 30 and 40 pounds per ton of finished product.

Where molten metal from a bessemer or open-hearth furnace is charged into the electric furnace for additional refining or finishing, the power consumption is greatly decreased, being about 30 per cent of the above figures; there is in such cases a corresponding drop in the costs for electrodes, refractories, etc. A Girod furnace is used for this purpose at the works of Societe John Cockerill, Seraing, Belgium, where they get ten heats daily.

The linings seem to stand very well, 40 to 50 heats being claimed, when partial repairs are made. The hearth proper seems to require but little attention; after about 100 heats, patching is required in the region of the slag line. The expense for refractories is said to vary between $1.50 per ton with small furnaces, to $1.00 for larger sizes.

Fig. 6 shows a 12 ton Girod furnace as installed at the works at Ugine, France. These works are unique in that the entire plant is operated by electricity, there being no steam plant in use whatever. Five Girod furnaces have been installed, two of 12 tons capacity each, and three smaller ones of 2 to 2 1-2 tons.

Girod claims a total of 17 furnaces at work, or under construction, an exceedingly rapid extension of the use of this type. The furnace seems well adapted to such uses as refining or finishing molten metal, making fine steel castings, and special fine steels of all sorts. A close inspection of the tables given indicate that this furnace is a very flexible piece of apparatus.

The Keller Furnaces: Charles A. Keller, of the Societe

des Etablissements Keller-Leleux, one of the earliest workers with electric steel furnaces, has developed several types of furnaces at the principal plant of his company, Livet, France.

There are two worthy of special mention, one of which includes a furnace having a conducting bottom, but differing essentially in construction from the Girod type. Fig. 7 shows a vertical section of a furnace with bottom thus constructed. Instead of having the metallic pole-pieces arranged peripherally, Keller has devised a system in which iron bars, 1 to 1.25 in. diameter are placed vertically over the entire bottom, with a space 1 to 1.25 in. between facing surfaces. Into these spaces is

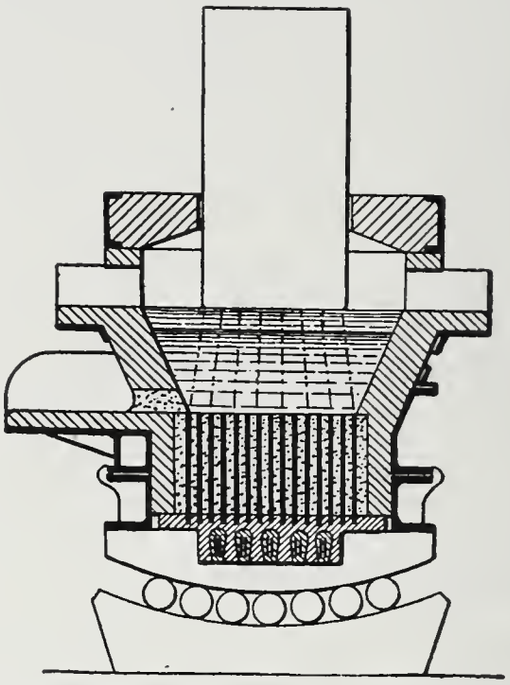

Fig. 7. Diagram of Keller Furnace, showing Bottom Construction.

tightly rammed a mixture of basic material such as magnesia, and a binder; the material being tamped in while hot. The result is an extremely compact mass of iron bars and magnesia. While the bottom is cold, as in starting up, the iron bars are good conductors, when heated, however, the magnesia being a conductor of the second class, also becomes conductive, and carries current. Thus in practice this construction becomes a conductor throughout its entire section. In the Girod type of furnace the lines of energy flow are perforce divided, seeking the several metallic pole pieces at the edges of the hearth, whereas in the Keller modification the energy flow is more uniformly

distributed, as Keller has indicated by the dotted lines, Fig. 7, between the lower face of the electrode and the contacting surface between the bath and conducting bottom.

A bottom thus constructed has considerable mechanical strength, resisting penetration by the bath to a marked degree. After several months' use a furnace of this kind was subjected to careful inspection, showing no deleterious changes. The rest of the furnace structure does not differ materially from other types.

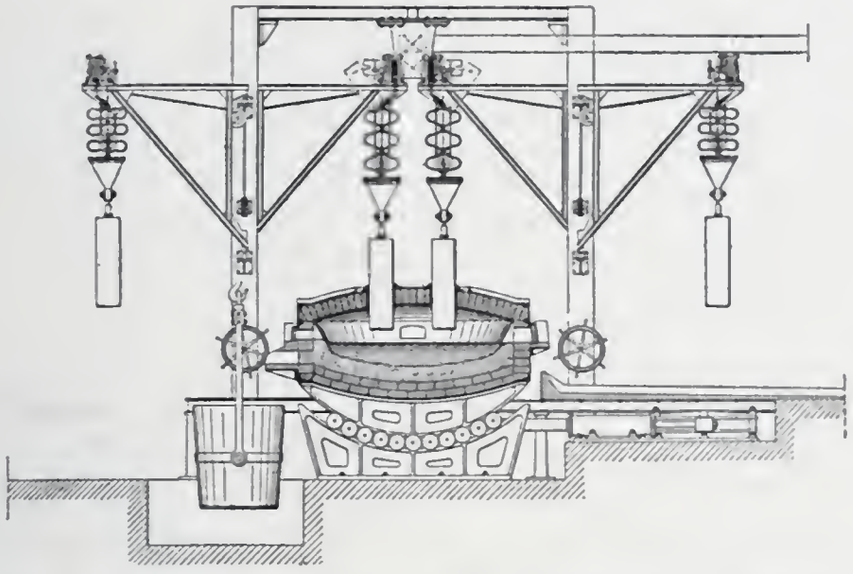

Fig. 8. Keller Furnace, with Electrodes in Series.

With this furnace, as with Girod's, three-phase current can be used, in which case it is fitted with three electrodes. Where the *Y* or *star* connection is used, the neutral point would be connected to the conducting bottom.

These two types, Girod's and Keller's, cover that class of furnaces having non-carburising semi-metallic conducting bottoms, and constitute a useful addition to our available apparatus, in that starting with cold charges of scrap is not difficult, and preservation of the roof is much easier.

However, there are certain disadvantages existing in furnaces of this type, which do not make their use always advisable. For furnaces of medium or small capacity they would undoubtedly give satisfactory results. But it is obvious that in furnaces using the same amount of power, the current density is twice as great as in the case of furnaces with electrodes in

series, where the bottom is not used as one of the poles. Moreover, such construction introduces a large inductive loop into the circuit, within which is the furnace body itself. This might have a serious effect on the power factor, unless special precautions were taken, such as the introduction of non-magnetic gaps in the furnace body and fittings, and avoidance of metals having high magnetic permeability inside the inductive loop. For such construction currents of low frequency are indicated. It is Keller's opinion that with a frequency of 20 cycles, a 1,000-kilowatt furnace, having a capacity of 10 to 12 tons. need not have a power factor less than 0.90.

Keller carried out a long series of experimental studies with furnaces having electrodes in series, i. e., where the path of the current is through one electrode to the bath, which is traverses, passing to another electrode, both electrodes being movably placed above the bath, as shown in Fig. 8.

As a result of these studies, a furnace of 8 to 10 tons' capacity has been installed at the steel works of Jacob Holtzer, Unieux, France. This furnace contains four vertical movable electrodes, there being two electrodes of like polarity, thus facilitating a more uniform expenditure of energy throughout the bath. The electrodes are so arranged that all four, or any particular pair, may be moved simultaneously, or any single electrode can be moved independently. With this arrangement regulation of voltage or amperage can be quickly and simply accomplished.

By arranging at equal distances around the furnace four vertical electrode supports, each carrying two arms, swinging right and left, respectively, it is possible to always have a spare electrode to replace the one in use, so that a change can be made in two or three minutes. It is also possible to replace any electrode without stopping the furnace, the current being carried temporarily by the remaining electrode of like polarity. Then by simply swinging all of the arms away from the furnace there are no overhead obstructions in case it is desired to remove or repair a cover.

Fig. 9 is a view of the Keller furnace at the Holtzer Steel Works, at the moment of making a cast of steel.

The furnace body is of steel plate construction, lined with magnesite. The furnace is fitted with the usual appurtenances, such as charging doors, tapping spouts, etc., and may be tilted in either the forward or backward sense to tap metal or slag.

This furnace is intended to take molten metal from a Martin open-hearth furnace, to be deoxidised refined and adjusted as to chemical composition. Steel having a percentage composition

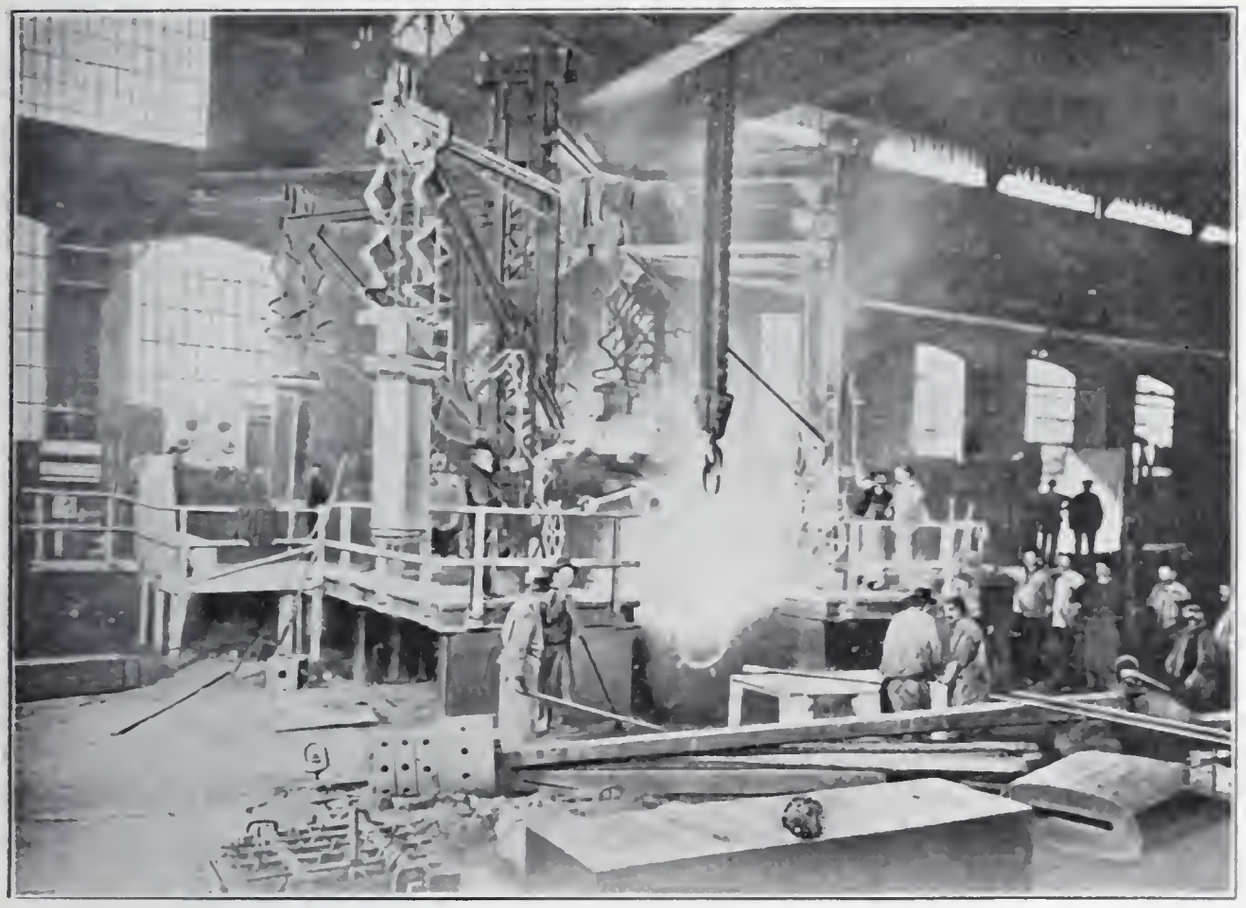

Fig. 9. Tapping Keller Furnace at Unieux Steel Works, France.

of 0.15 carbon, 0.06 sulphur and 0.007 phosphorus is refined to about 0.015 sulphus and phosphorus. The furnace will handle about 8 tons of metal in 2 hours and 45 minutes, with an energy expenditure of about 275 kilowatt hours per ton.

The electrode consumption averages 80 cents per ton, while all the necessary manual labor is taken care of by one melter and three laborers. The following are some mechanical tests of Keller's steel, made upon test pieces 13.8 mm. diameter and 100 mm. between marks:

	Elastic limit Lb. per. sq. in.	Ultimate strength Lb. per sq. in.	Elongation Percent
1 (longitudinal)	86 300	112 000	17.0
2 (longitudinal)	86 300	113 000	16.5
1 (transverse)	86 300	112 000	14.0
2 (transverse)	88 000	112 500	14.0

Table No. 4—Mechanical Tests of Keller's Steel.

These tests were made upon steel produced to fill a foreign order, calling for material of armor plate quality. The analysis was as follows:

Carbon	0.30 percent.
Silicon	0.20 percent.
Manganese	0.56 percent.
Sulphur	0.007 percent.
Phosphorus	0.015 percent.

A recently published list gives Keller credit for having six of his furnaces in use at this time. The type having electrodes in series does not differ greatly from the Heroult furnaces, except as to details.

The Heroult Furnaces Heroult has recently adhered closely to the type of furnaces with electrodes in series, according to the principle illustrated in Fig. 8. This design approximates closely in the shape of the hearth, roof, etc., to a small open-hearth furnace.

Furnaces of this type are undoubtedly capable of expeditiously melting impure scrap materials and refining the metal to a high degree of purity. The following table gives the average analysis of a large number of heats, as carried out in a 2½-ton furnace at La Praz, France:

	S	P	Mn	Si	C
Scrap charged	0.052	0.150	0.638	0.062	0.211
Finished steel	0.006	0.009	0.254	0.172	1.013

Table No. 5—Refining in Heroult Furnaces.

The energy and electrode consumption do not differ materially from other types of electrode furnaces.

The most interesting development of the Heroult type of furnace is the installation at the South Chicago Works of the Illinois Steel Co. A front view of this furnace is given in Fig.

10, and in the tilted position in Fig. 11. The furnace has a nominal capacity of 15 tons, and is designed to use three-phase current, with three electrodes, the power being supplied from three separate transformers of 750 kilowatts capacity each. The electric power used to operate this furnace is generated at Gary, Ind., and transmitted from thence to South Chicago, the power supply at these two locations, 40 miles apart, being connected in parallel.

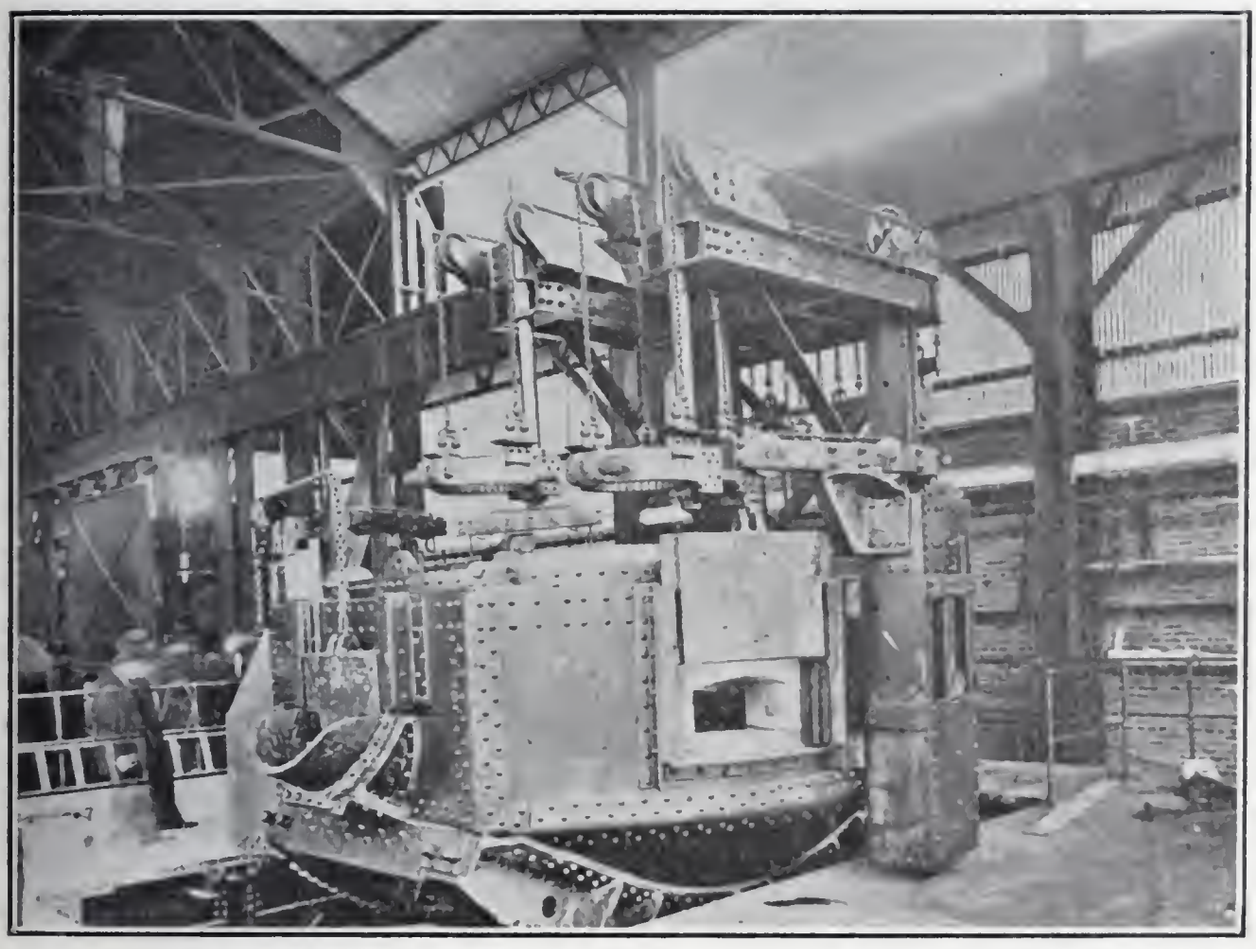

Fig. 10. Front View of Héroult 15-ton Furnace, South Chicago.

Prior to this installation, the first heat in which was made in May, 1908, the largest furnace Heroult had attempted was about 5 tons capacity. Hence the South Chicago furnace was revolutionary from the fact that the quantity of metal in the bath was trebled, and that three-phase current was to be used.

Another innovation was the coupling of acid bessemer and electric furnace treatment as a duplex unit. Certainly the United States Steel Corporation is to be commended for its courage in these respects.

Practically the entire gamut of steel products has been run with this installation, such as ordinary and special steel castings, rail steel, axle steel, tool steel, both alloy and carbon, as well as various grades of manganese steel. The results are said to have been satisfactory in each case, thus demonstrating a wide field of application.

The standard practice at South Chicago is to charge the furnace with molten acid bessemer metal, slightly overblown,

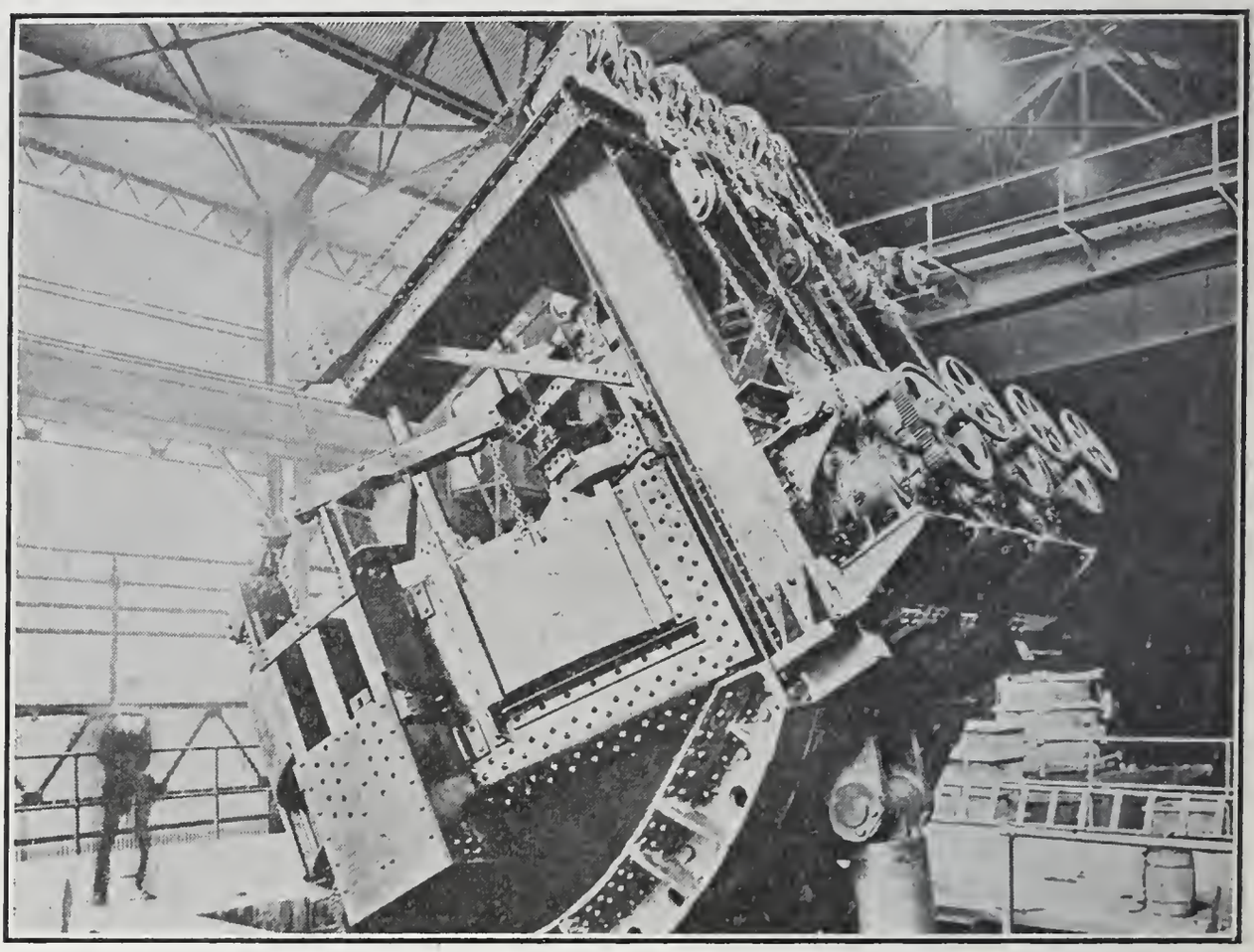

Fig. 11. Héroult Furnace, South Chicago. Tilted.

and to use two refining slags in the electric furnace; the first a dephosphorising slag; the second a deoxidising slag to eliminate sulphur and gases.

It is obvious that the consumption of electrical energy will vary according to the amount of refining to be done, and with the time the metal is in the electric furnace. In *Metallurgical and Chemical Engineering** some interesting data are given,

*Issue of April 10, 1910.

showing this variation in energy consumption between 100 and 200 kilowatt hours per metric ton. From the same article it will also be noted that the temperature of the bessemer metal is charged is about 1 500 deg. cent. and that the temperature of the metal as tapped from the electric furnace is in the same neighborhood. Hence it is apparent that the furnace is being used to maintain the temperature, i. e., supply radiation losses, during the period of refining, the advantage being that such refining can be done under the controlled conditions possible with electric furnaces.

The tonnage capacity of such a furnace is exceedingly gratifying. Repeatedly 13 heats of about 14 tons each have been made in 24 hours, thus showing a daily record of about 180 tons, or in the vicinity of 1 050 tons per week of six days, it being the practice to shut down over Sunday, when the bessemers are not blowing.

At first some trouble was experienced with the carbon electrodes, as it was found that trustworthy amorphous carbon electrodes of the large dimensions required were not yet possible of production. Graphite carbon electrodes, built up from smaller pieces have given good results, and as several companies are engaged in research work on amorphous carbon electrodes of large dimensions, there is reason to hope for an early solution of the amorphous carbon electrode problem; these being considerably less expensive per pound than graphite carbons. The electrode consumption, per ton of steel produced, is given as about seven pounds, which is not discouraging at all considering the youth of the apparatus.

Inasmuch as the furnace is not being used to greatly increase the temperature of the metallic bath, the matter of refractories has not given much trouble. The habit is to throw some basic lining material onto any affected portions between heats. Burnt dolomite is generally used, the quantity required being about 10 pounds per ton of product, which is insignificant. The total cost for refractories, including silica roof renewals, is said to be under 10 cents per ton of steel.

At the Worcester Works of the American Steel and Wire

Co. the United States Steel Corporation has installed a similar furnace. The practice here will be, however, to charge molten metal from basic open-hearth furnaces, thus constituting an open-hearth-electric duplex unit. The product is to be mainly super-refined steel for special wires.

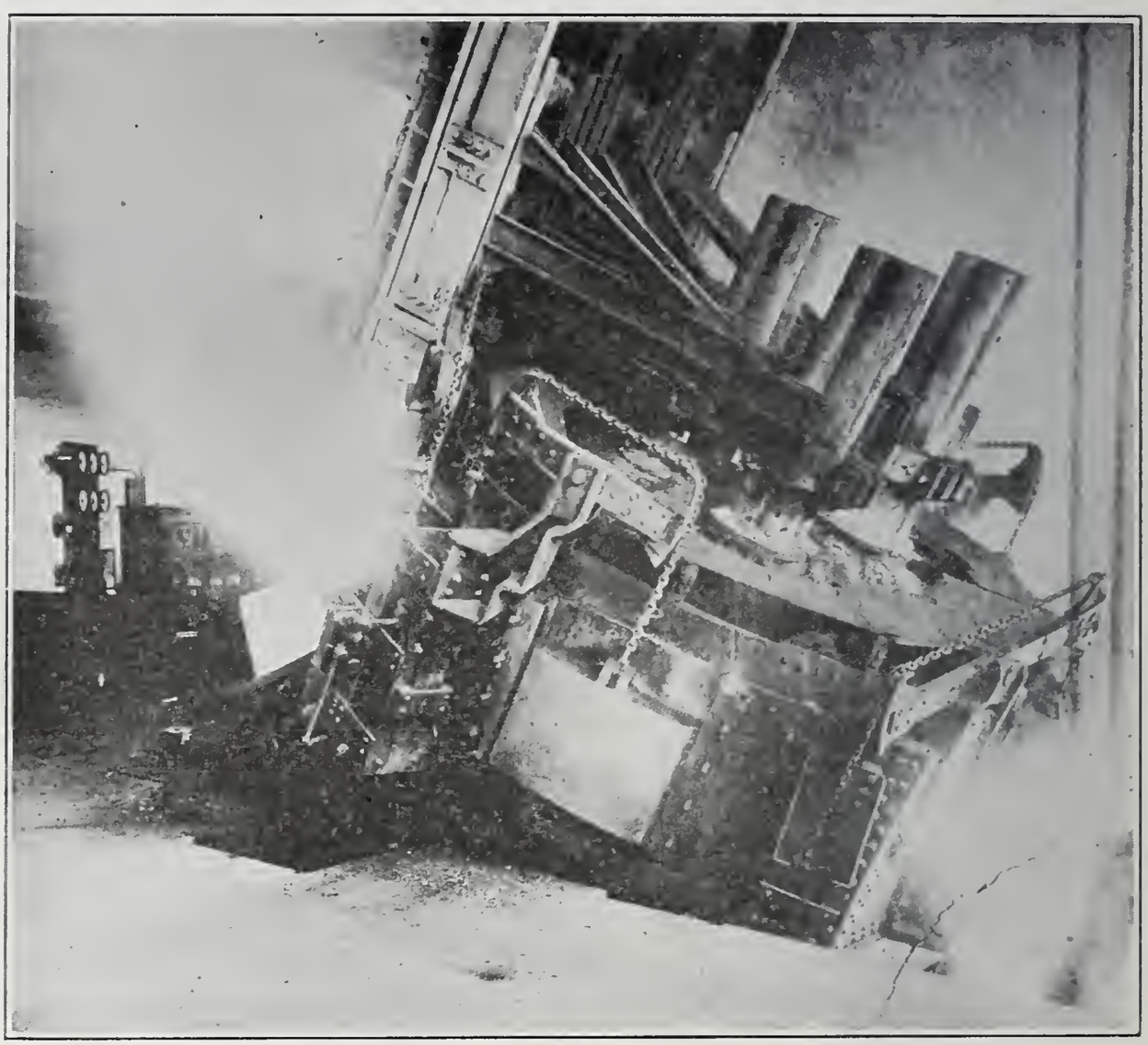

Fig. 11a. 15-ton Héroult Furnace at Worcester Plant, American Steel & Wire Co.

The announcement has just been made that the Steel Corporation has finally decided to acquire the Heroult patents in this country, from which the conclusion may fairly be drawn that the technical results attained are sufficiently good to warrant this move.

Published lists give 25 Heroult furnaces now installed, four of which are in the United States. This development has all taken place since 1903, and mostly within the past five years.

Finally it may be noted that furnaces of the Girod, Keller and Heroult construction all depend upon supplying heat to the metal by conduction from the highly-heated supernatant slag, there being no appreciable heating due to passage of the current through the metal itself.

Electric Induction Furnaces: We may now consider a type of furnace radically different from those previously described, in that no electrodes are used. The induction furnace is a case of almost simultaneous invention by Colby in the United States and Ferranti in England, and later put to commercial use by Kjellin, in Sweden.

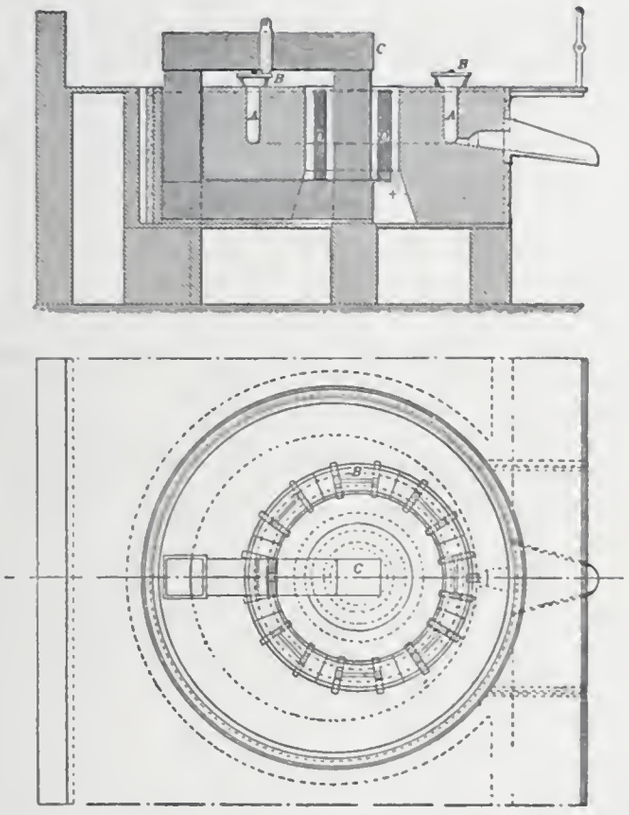

Fig. 12. Diagram Showing Principle of Induction Furnace.

The principle of the simple type of induction furnace is shown in the diagram, Fig. 12. From the engineering point of view the induction furnace is really a highly developed piece of apparatus, consisting of a transformer in which the metal under treatment forms a closed secondary circuit, having but a single turn. The apparatus includes a magnetic circuit, *C*, formed of the usual laminated sheet iron, as in a transformer core. Electric energy is supplied to a primary coil, *D*, while the secondary circuit is formed by the ring of metal under treatment, con-

tained in the annular cavity *A* forming the crucible. The most satisfactory refractory is some basic material such as calcined magnesite or dolomite. Now, when energy, in the form of alternating current, is supplied to the primary coil *D*, it creates a varying magnetic flux in the laminated iron core, which in turn induces a current in the closed secondary circuit consisting of metal in crucible *A*. The current density in the secondary bears a fixed ratio to the number of turns in primary coil *D*, so that it is possible by a suitable variation in impressed voltage to subject the metal to extremely heavy current densities, the heat being thus produced by the Joulean effect simultanously throughout the entire mass of the metal bath. This is a unique characteristic of the electric induction furnace, it being theoretically possible to raise the temperature of a bath of metal from a given temperature to any desired higher temperature in a few minutes. This, however, is not done in practice for various reasons, one being the violent strain produced upon refractory containers by such rapid changes in temperature. There is another limiting feature to the current which may be passed in the "pinch" phenomena, noted by Mr. Carl Hering, where the ring of metal tends to break when a certain point is passed.

This type of induction furnace is extremely well adapted to the melting of pure materials, such as would be used in crucible steel practice. It is not possible, however, to start with cold scrap as in the cases of electrode furnaces. The bath must first be established by other means; upon first starting up the induction furnace, the practice is to melt down a ring of metal previously placed in the furnace, and then feed in additional material until the full quantity shall have been charged. Then, upon tapping it is customary to leave approximately 30 per cent of the metal in the furnace to furnish a bath for subsequent operations.

This particular type of induction furnace does not readily lend itself to extensive refining operations, nor, in all fairness to those interested in its commercial exploitation, be it said, has it been advocated as an ideal apparatus for such purpose

There is but a limited contact area between slag and metal

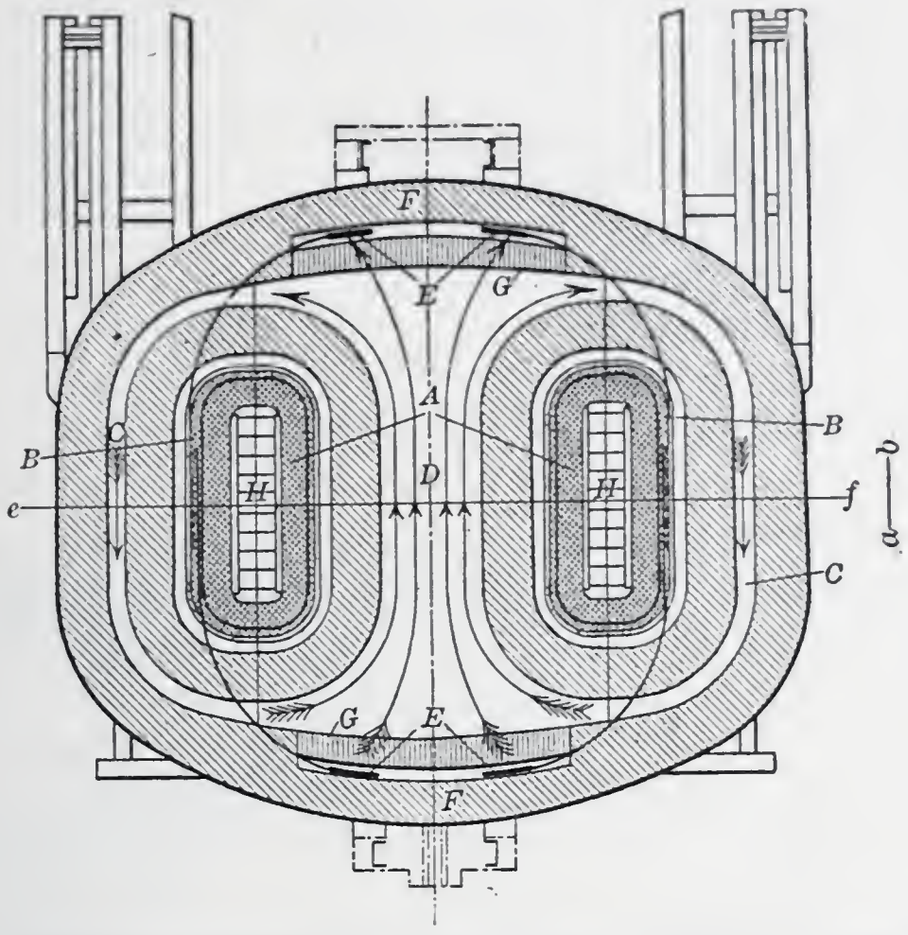

Fig. 13. Röchling-Rodenhauser Single Phase Induction Furnace, plan.

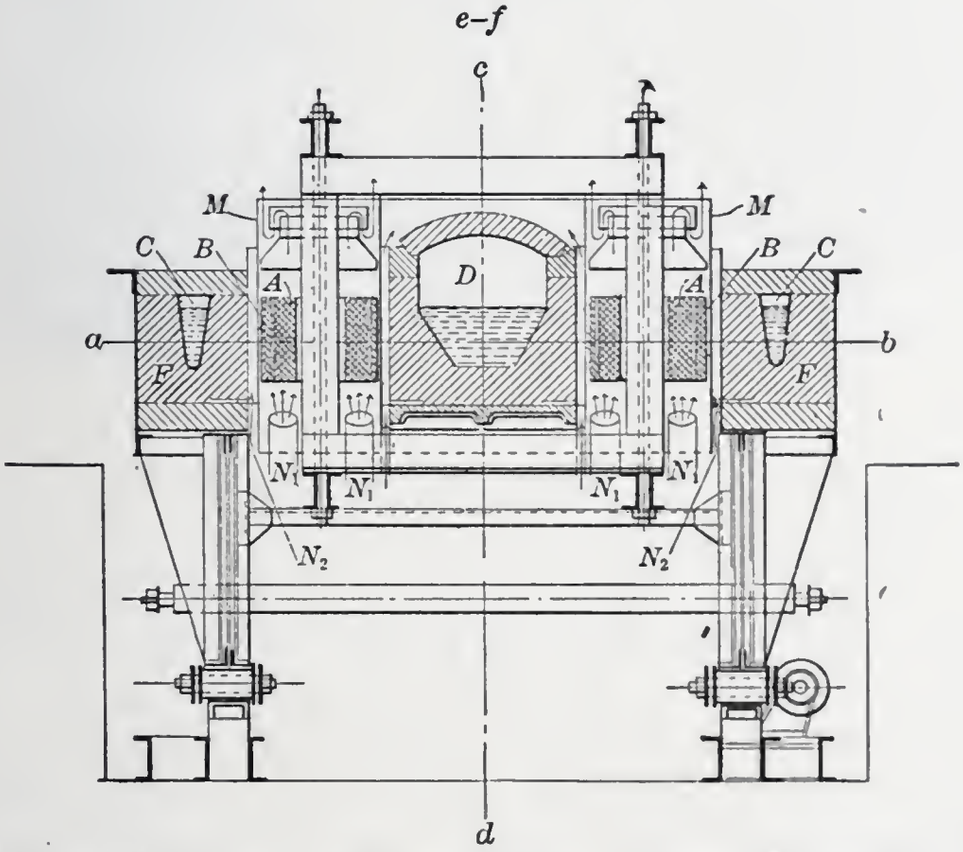

Fig. 14. Röchling-Rodenhauser Single Phase Induction Furnace, transverse elevation.

which militates against rapid refining. There is also a certain scouring action produced upon the crucible walls by a characteristic gyratory motion of metal and slag.

As a purely melting apparatus, however, it seems to be ideal, its thermal efficiency being usually high. Its principal application will, therefore, be for production of high-grade tool steels, in competition with the crucible method. A small furnace of this type, using about 125 kilowatts, can easily deliver 800 lb. of metal per heat, with an energy expenditure of about 600 k. w. h. per ton. The total cost shows decided advantages over the crucible method.

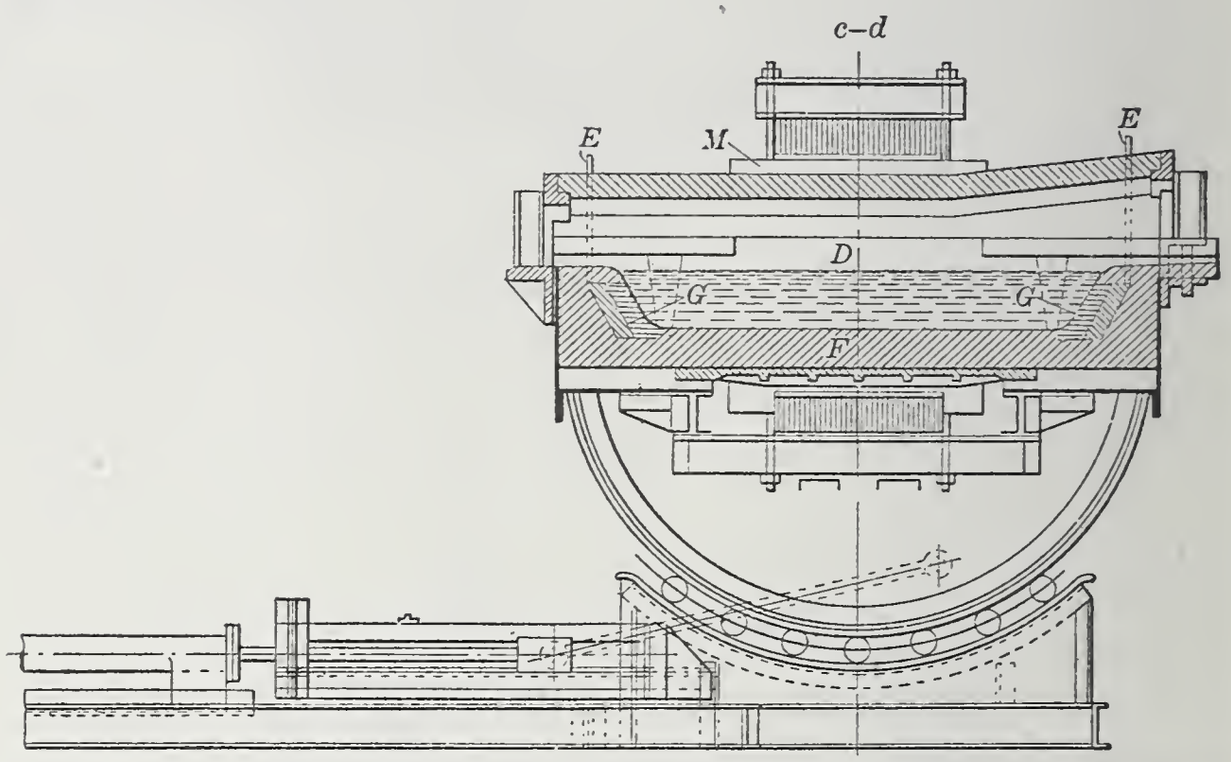

Fig. 15. Röchling-Rodenhauser Single Phase Induction Furnace, longitudinal elevation.

Of this this system about ten furnaces are now in use in various places.

The usefulness of the induction type of furnace has been considerably broadened, however, by an interesting modification introduced by Messrs. Rochling-Rodenhauser of the Rochlingische Isen und Stahlwerke, Volklingen, Germany. This type, which will be alluded to as the *R-R,* has been built for single-phase and three-phase power. Figs. 13, 14 and 15 show the single-phase design in plan, transverse and longitudinal sectional elevations, respectively.

The furnace is practically two single induction furnace crucibles combined, the adjacent portions of the annular cavity widening to form an open chamber, which becomes the main or working hearth In this central chamber are placed auxiliary current terminals, shown in Fig. 13, consisting of steel plates *E* faced with a mixture of refractory material *G* which has the property of becoming a good electrical conductor when heated. Therefore, in addition to the current induced in the rings of

Fig. 16. Röchling-Rodenhauser Eight Ton Single Phase Furnace, tilted.

fluid metal *C-C* a considerable portion of the total energy input is diverted and made to pass through these terminal plates, and directly to the bath. The result is claimed to be an appreciable gain in the power factor of the apparatus, an important consideration when purchasing outside power.

Differing from the simple type of induction furnaces, this modified style has been successfully used for the treatment of molten steel charges. Prior to the advent of the 15-ton Heroult furnace, it is not out of the way to say that the major portion

of the total tonnage of electric furnace steel was the product of *R-R* furnaces. Considerable quantities of rail steel have been made by this furnace in Germany, the product having been rolled into finished rails, and used with satisfaction under extremely onerous conditions. By the use of suitable slags it is possible to bring the phosphorus down to the desired figure in a single operation; but for making the highest class of steel, two

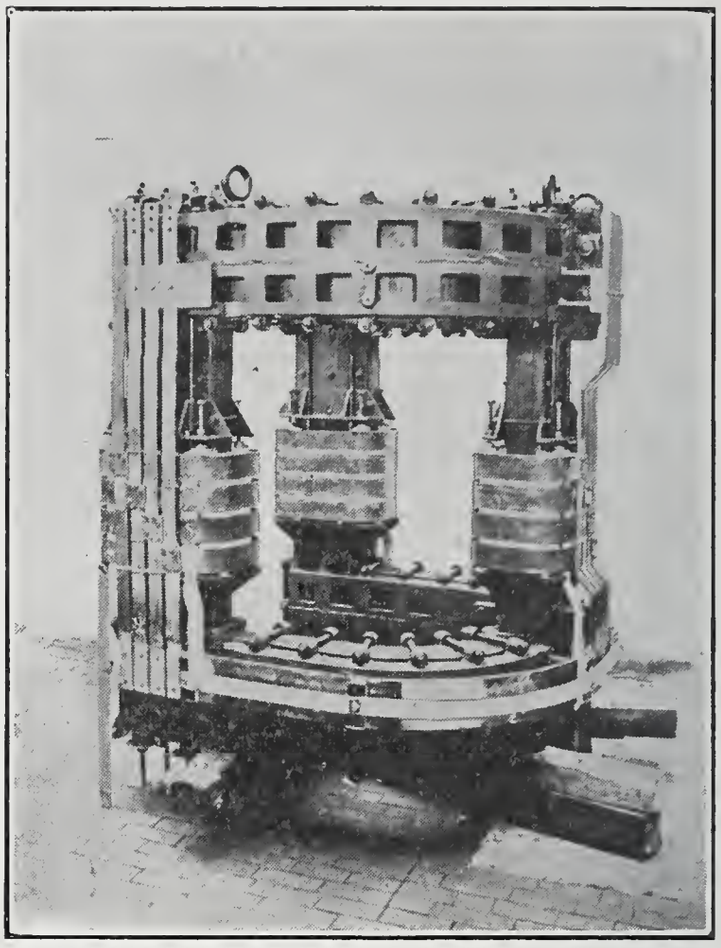

Fig. 17. Röchling-Rodenhauser Transformer Core for Three-Phase Furnace.

slags are used. Fig. 16 is an illustration of a single-phase *R-R* furnace, in the pouring position. This furnace has a capacity of 8 tons per charge, using 700 kilowatts, at 5 cycles. The power factor is given as 0.80, but it is obvious that at higher frequency would be considerably lower.

Under modern conditions of power supply it is seldom that single-phase power can be bought advantageously, even at commercial frequencies. Three-phase power seems to hold the field at present, so some *R-R* furnaces, adapted to use three-phase

current, have been constructed. The transformer portion of one of the smaller sizes is illustrated in Fig. 17. The laminated core consists of an upper and a lower horseshoe shaped member, joined by three legs, upon each of which a primary coil, representing one-phase, is wound. All of the *R-R* furnaces for some time past have been provided with means for cooling the primary coils and laminated iron core by air-blast as preferable to water-cooling.

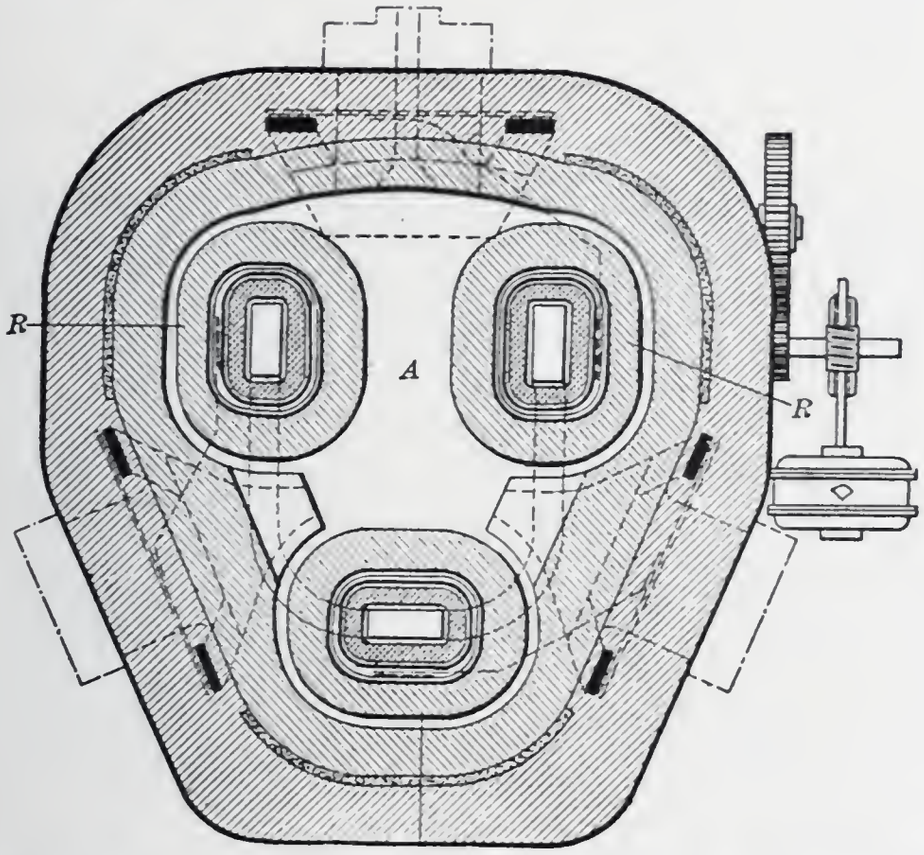

Fig. 18. Röchling-Rodenhauser Three-Phase Furnace Plan.

Fig. 18 shows a plan view of a three-phase *R-R* furnace, from which it may be noted that adjacent portions of each annular space are opened out to form a common hearth between them. In this open portion any desired manipulation with slags, ores or alloys is readily accomplished, the circulation in the annular portions constantly bringing fresh metal into the central hearth.

The terminals carrying auxiliary current are, in the case of the three-phase furnaces, placed between each of the three legs. Compared to the single-phase furnace the three-phase type has the advantage of maintaining a more satisfactory power factor

when using commercial frequencies. One such three-phase furnace of 3 000 lb. capacity, working at 50 cycles, showed a power factor of 0.75 to 0.80. Fig. 19 shows a furnace in the act of pouring a heat.

At the Rochling Steel Works a number of induction furnaces have been in regular service for some time, treating molten charges to be refined to mild steel. The power consumption is very satisfactory, between 200 and 250 kilowatt hours per ton of product. A heat can be completed, according to circumstances, in from 1 hour 45 minutes to 2 hours 45 minutes. Many tons of electric furnace steel have been supplied from these works for the Prussian State Railways, and the London underground roads. The following is an interesting table of chemical and physical results, the mean of six tests of electric furnace rail metal and 16 tests of Thomas, basic bessemer, rail steel:

	Composition.					Tensile strength lbs. per sq. in.	Elongation percent	Contraction percent
	C.	P.	S.	Mn.	Si.			
Electric Steel ..	0.54	0.056	0.042	0.984	0.21	119,000	15.4	24.1
Thomas Steel ..	0.30	0.073		1.127		97,000	17.6	26.2

Table No. 6—Tests of Electric Furnace and Basic Bessemer Rail Steel.

In explanation of the above figures, it should be noted that the electric furnace steel rails have shown in tests a greater toughness than Thomas steel rails of same carbon content. Therefore, it has been possible to increase the hardness, and hence the life, of rails by using the electric furnace product of somewhat higher carbon content, still leaving the rails fully as tough as the milder Thomas steel rails. A similar result having been remarked in the case of carbon steel rails, made from the Heroult furnace at South Chicago, it would be interesting to ascertain whether this is not characteristic of the electric furnace product generally.

About 15 furnaces of the Rochling-Rodenhauser types are now said to be in use, and it is understood that several have been decided upon in the United States.

The products are mostly extra-refined mild steel, high-grade tool steel and steel castings

As to the performance of the furnaces themselves, a satisfactory refractory cost is claimed. It is the practice at most works to shut down the furnace Saturday noon until the following Monday morning, during which interval the lining may be repaired or renewed. A production of 1,200 tons of rail steel with a single lining is claimed. Electrode consumption and troubles are eliminated, to compensate for the probably greater cost for linings.

Fig. 19. Röchling-Rodenhauser Two-Ton Three-Phase Furnace, pouring.

The foregoing illustrates the impotrant types of electric furnaces now in use for steel making. There are a number of others, principally experimental or confined to solitary installations at the present time.

Development of Electric Furnaces: Now that you have a notion of the tools we have to work with, let us consider the uses to which they may be put.

First, as to high-grade steel, of crucible quality, the electric furnace is destined to become a serious rival of the crucible method simply because it is less expensive. This is especially true of the larger works, where tonnage becomes of moment. On one hand are high cost for labor, crucible renewals, the necessity of melting in small units. On the other a low labor cost, low cost of refractories per ton of product, the possibility of handling several tons of metal of uniform composition; and ability to do in the furnace itself certain refining that must otherwise be done before the metal is put into the crucible.

There are six electric furnaces in this country regularly producing steel of crucible quality, two of them in the Pittsburgh district.

Second, for steel casting, the electric furnace promises to appropriate to itself a considerable field. It cannot and does not aim to displace open-hearth steel castings; but for a grade of castings somewhat better than open-hearth product, cheaper than the crucible product, and for which there is even now a crying need, the electric furnace has found a place in which its popularity is certain to increase.

I have in mind now one very large manufacturing company, well known to you all, which built for itself an experimental electric steel furnace, of several tons capacity. Having occasion to require some steel castings at short notice, some molders were sent from the company's foundry into the building where the furnace was erected, to make an attempt to get out the castings, using electric furnace metal. The results exceeded all expectations to such an extent that within two months the furnace was moved into the foundry, where it is now a regular and much-used part of the equipment.

Third, the electric furnace is not claiming rivalry with the bessemer or open-hearth furnace as a steel producer, for ordinary grades of structural and similar steel. Rather it is to be considered as a useful accessory, or ally, of the older methods. It offers an opportunity to do additional refining or special treatment in an expeditious manner secondary to other operations.

Owing to enforced changes in the character of available raw

materials existing bessemer and open-hearth plants are often compelled to use products for which their apparatus is not perfectly adapted. The electric furnace, taking molten metal from either the bessemer or open-hearth, opens the way to a duplexing process that may save much valuable plant from the scrap heap.

It will be observed that in this country, so far as the United States Steel Corporation is concerned, one of its electric furnaces is duplexing with an acid bessemer, and the other with basic open-hearth.

It is interesting to note that the vital parts of German Government dirigible balloons, such as the Parseval and Zeppelin, were of electric furnace steel from the Bismarckhutte. Was this selection due to the greater trustworthiness of electric furnace steel? The Italian company making the celebrated "FIAT" automobiles uses considerable quantities of electric furnace steel castings for vital parts of the car. At the recent Brussels Exhibition, a large part of the steel exhibits was of electric furnace steel, almost the entire Cockerill exhibit being devoted to such products. Here is a suggestion for the annual Pittsburgh Exposition.

Until recently metallurgists who have acquired the mental habit of thinking in hundreds of tons, grumbled because the electric furnace was only a plaything, a toy, and said that when a furnace of fifteen tons capacity could be shown, it would be worth while. Well, "the man from Missouri" has been shown, and now he grumbles because it is not thirty tons.

The electric furnace engineers, knowing the proclivities of the metallurgist, have been preparing to forestall his demands, by opening the way to still larger furnaces.

The matter of suitable carbon electrodes soon became of prime importance in furnaces of that type. The limit of size with existing carbon machinery was reached, but still the demand arose for larger and longer electrodes. Serious investigation and research is now being made looking toward the production of electrodes as large as 30 inches diameter and ten feet long. There are several companies preparing to make such electrodes, and there is hardly doubt that this problem will be solved in time.

Refractory materials present a problem by themselves. Much work is being done along this line, with the result that several improved materials will soon be offered. One that I have in mind consists of electrically-fused alumina, making a brick that is fairly inactive chemically at furnace temperatures, and this material gives great promise. Generally the roof has been short-lived in the larger steel furnaces, probably due to the chemical activity of lime, silica and iron vapors in the furnace. Any refractory material that will stand the high temperatures, and prolong the life of the roof, will mark another step forward. It is curious to note that so far the most promising new refractories are themselves products of electric furnace treatment, so it seems that the electric furnace must solve its own problems largely. Take the matter of electrodes, the best results have been obtained from graphitised carbon, which treatment has had to be done in the electric furnace.

Throughout the world there are now about 75 electric furnaces devoted to steel products. As to the capacity of such when it is considered that a furnace, such as the ones at South Chicago and Worcester, have a capacity over 1,000 tons per week, we can justly claim that for steel refining the electric furnace has put off its swaddling clothes for the more dignified garments of manhood.

It is certain that during 1910 at least 150 000 tons of steel products can be claimed for electric furnaces.

A New Metallurgy: Reference has been made to a new metallurgy connected with electric steel furnace practice. It was to be expected that new conditions would be productive of new methods. Electric furnaces differ from bessemer or open-hearth furnaces in that the atmosphere above the bath is under greater control. It is well understood that the older metallurgical processes, bessemer and open-hearth, actually depend upon oxidizing conditions for their results, and their metallurgy is based upon the chemistry of oxidized compounds. Instead of being forced to work under such conditions, with the electric furnace we can work under non-oxidising conditions, either neutral or actually reducing.

Therefore, electric steel furnaces present new metallurgical conditions to the steel maker, with the result that a new metallurgical practice is being developed.

It has been conceded to the electric furnace by many who have studied the matter, that with reference to the elimination of oxides, sulphur and phosphorus, the electric furnace is capable of rapidly removing such deleterious impurities to an almost unprecedented degree. Certain it is that no matter why, the electric furnace is an efficient remover of certain things regarded as undesirable in steel. This is one striking characteristic of the new metallurgy—improvement in quality by the removal of impurities rather than by rendering them harmless with alloys, etc.—a preventive rather than curative treatment. Prof. H. W. Harboard has written an interesting paper on "The Electric Refining of Steel" with particular reference to the reactions supposed to occur under electric furnace conditions, resulting in the elimination to a high degree of such impurities as oxides, sulphur and phosphorus.

Now to what extent have new conditions modified metallurgical results? First, ability to remove oxides, or oxidising gases. Second, it has been conceded that electric furnace treatment can remove sulphur and phosphorus to almost the last degree. Sulphur in steel is chemically combined with iron and manganese. In basic furnaces these *sulphur* compounds will pass into the slags. But as these sulphur compounds are also soluble in the steel, their complete removal will not occur, but only in proportion to their respective solubilities in slag and metal bath. In the electric furnace, on the contrary, conditions permit the formation of the reduced compound *calcium sulphide, CaS,* and this *calcium* compound, as distinguished from iron or manganese sulphide, is not soluble in the bath, hence its removal in the slag is easily possible.

Phosphorus is removed in basic furnaces in the presence of an oxidising atmosphere as phosphate, an oxygen-containing compound. In the electric furnace, by the use of carbon, ground coke for instance, the phosphate may, by reason of the reducing or neutral atmosphere possible, be converted into the reduced

compound calcium phosphide. Once in that state and with the atmosphere maintained, it remains in the slag. Hence it is easy to see from the observations made during the very childhood of electric steel refining, the birth of a new metallurgy that may go so far as to modify in some degree present day practice in older processes. It is a fact, however, that nothing is specifically done in electric furnace practice to remove nitrogen, an element which seems to be the target for the metallurgists' bad graces at present. As titanium, or vanadium, readily forms nitrides, it may be that a small addition of their ferro-alloys would be justified by results. Both of these it may be worthy of note, are electric furnace products.

Thus it is that not only in the amelioration of defects in steel made by present processes, but possibly in suggested improvements in those processes, the electric furnace may now claim recognition from the older industry.

DISCUSSION

MR. H. W. FISHER: I would like to ask how furnaces of the kinds mentioned are started. The materials used have not a sufficiently good conductivity when cold and hence when starting a furnace, some path of low resistance between the electrodes, must be provided.

THE AUTHOR: In the case of starting a furnace with molten metal, the charge being added in liquid form, there is a bath formed when charged. In the case of starting cold, it has been the practice to start with iron rings which are heated up to the melting point and the bath thus formed.

MR. H. W. STORER: I would like to inquire what effect the frequency has in this induction furnace. You spoke of reducing it to five periods.

THE AUTHOR: The higher the frequency the lower the power factor. Therefore to get a good power factor it is desirable to work at as low frequency as possible. Of course in some places it is not possible to get low frequency current, and for a complete installation it would be necessary to put in ap-

paratus giving a low frequency; that is why I say it involves a lot of electrical plant to have the furnace working under the best conditions.

Mr. J. O. Handy: I have in mind a deposit of magnetite iron ore which contains from three to five percent sulphur. Do you think it would be better practice to make electric furnace iron from this ore direct, or would you roast the ore first? I ask this because it seems possible to make high grade steel from very crude iron by use of the electric furnace.

The Author: Theoretically it ought to be possible to work with far higher sulphur content in the electric furnace than in the blast furnace; but so far as I know no successful experiments have been made. I know of several unsuccessful ones.

Mr. C. F. Scott: It is interesting to note how universally useful electricity is becoming. It can be so readily transformed and adapted to various purpases that it is becoming generally utilized in almost all branches of engineering. One of the principal reasons why it is so generally applicable is the facility with which it can be transformed and controlled. Although some forms of electric regulators have been the object of rather slighting references by the Speaker of the evening, nevertheless, it is this readiness of transformation and control which is the fundamental reason for the use of electricity in the steel furnace. In fact it is this same facility which enables electricity from the same generator and the same circuits to be applied in tremendious quantities in furnaces, or to be utilized for small motors, flat irons, or lamps.

Alternating current is the form of electricity commonly used in electric furnaces, largely because of the readiness by which it can be produced and controlled. There is, however, one characteristic of the alternating current which often involves a serious difficulty. This feature is that an electro-motive-force in addition to that necessary for overcoming the ordinary resistance of the circuit is required. This additional electro-motive-force is generally greater in proportion as the

current is large, as the electro-motive-force of the circuit is low, and as the frequency is high. In furnace work, a large current is necessary and this must be applied at a low voltage. It is, therefore, desirable to operate at a low frequency. On the other hand, it is often difficult to generate a current of low frequency. A frequency of five cycles, which was mentioned during the evening, is one-fifth of twenty-five cycles which is a frequency commonly used in power work. This frequency of five cycles expressed in another way is 600 alternations per minute. This would be produced in a generator having two poles, running at 300 r.p.m., or by a four pole machine at 150 r.p.m. The highest possible speed for generating this frequency is, therefore, 300 r.p.m. which is below the economic speed for many types of water-wheels, steam engines, and turbines. Furthermore, the size and cost of electrical machinery for low speeds is considerably greater than for high speeds. Consequently very low frequency is undesirable from the electric generating standpoint.

In an alternating circuit, the voltage required in excess of that which would be necessary for sending direct current through the circuit depends very largely upon the physical position of the circuit. If the two conductors are placed very close together, the effect is small. If the conductors are widely separated, forming a large loop or circle, then the excess voltage is higher. If there is iron surrounding the electric conductors, then the excess voltage is still higher, as it is caused by the magnetic field which passes between the outgoing and return conductors, this field being produced by the current in the circuit. It is, therefore, obviously desirable that when heavy current is to be supplied to a furnace that the transformer should be as close as possible to the furnace in order that the length of the circuit may be short. It is also desirable to have the outgoing and return conductors close together. In some cases it is practicable to interlace the conductors, for example; flat bars which are insulated from one another are placed side by side, the odd bars carrying the current in one direction and the even bars in another direction. The ratio between the

useful voltage (i. e., that which would be required for supplying power to the circuit for overcoming resistance and to produce heat in the furnace) and the actual voltage required for sending the current through the circuit is termed the power factor. The lower this power factor, the greater must be the voltage supplied and the larger the electrical apparatus for supplying it. Generally speaking the intelligent use of twenty-five cycle current involves a power factor which does not inordinately increase the size and cost of the electrical apparatus. If, however, 60 cycles be used, particularly if the current be quite heavy, the voltage low, and the conductors indifferently placed, then the excess may be a very serious handicap.

The several points of frequency, the design and placing of the transformer, the arrangement of the leads connecting the transformer to the furnace, the control apparatus and the kind of electrodes to be used, render the problem one which is electrical as well as metallurgical, so that for efficient results it is quite essential that an installation be properly designed from the electrical as well as the metallurgical standpoint. Success requires the knowledge of the practical and theoretical electrical engineer as well as the practical and theortical metallurgist.

Mr. F. N. Speller: My experience with the electric furnace has been rather limited. It has been concerned chiefly with the attempt to make low carbon steel for the manufacture of welded or seamless tubes, and I am sorry to say has not been particularly encouraging. The difficulty seems to be principally one of controlling the percentage of carbon in the finished steel, due perhaps to the quality of the electrodes which we have had to use so far. But the limited experience we have had is not such as would warrant any conclusion, except to point out the difficulty in obtaining uniformity of results in making low carbon steel. Perhaps Mr. Bennie can give us some encouragement along this line.

The Author: You mean you get an un-uniform carburization from the electrode?

Mr. F. N. Speller: Very likely.

THE AUTHOR: If that is the only trouble I am inclined to furnaces of the induction type where you do not have carbon.

MR. F. N. SPELLER: We have not had the advantage of experimenting with that particular type of furnace.

MR. P. P. REESE: I would like to ask Mr. Bennie where it is possible to find out something more about that fused alumina brick. One of our troubles is in keeping the roof on the furnace. We used a nine inch silica brick and we tried a thirteen inch silicia brick and we did not get any more life out of the latter than the nine inch. I think it is due partly to what Mr. Bennie said, the action of the lime fumes on the silica, but I think it is mostly due from reflection of the arc. We can string the furnace roof in one heat. We do not do it as a rule because we try to glaze the roof first. But the roof on the furnace is quite a problem just now. With our side walls we have very little trouble. For that reason I think it is due to the reflection of the intense heat against the roof.

THE AUTHOR: What is the nature of the side walls?

MR. P. P. REESE: The same, silica brick.

THE AUTHOR: Wouldn't the arc reflect just as strongly sideways as above?

MR. P. P. REESE: It can't get at the side walls so easily on account of the slag forming a shield.

THE AUTHOR: So far as the fused alumina brick is concerned if you will write to the Speaker we will be very glad to tell you where you can get them. It is not a matter altogether of public knowledge but we will be very glad to help anybody who is in trouble.

MR. BRENT WILEY: I noticed at the meeting last summer of the Electro-Chemical Society in Pittsburgh, a good many of the steel casting foundry people were interested in the furnace proposition and I would like to inquire if you have investigated the proposition in regard to the commercial aspect of the small casting, ranging from five to 20 lb. I would like to know about what would have to be the selling price of castings within that range to be a commercial proposition.

THE AUTHOR: That is something I would not answer off hand. The electric furnace is being used for small castings now in a number of places, more particularly in Switzerland, Germany, France and Italy, instances of which are mentioned in the paper, with most excellent results in such castings as parts of steering knuckles and some very thin castings. As to the cost of these that will depend on the nature of the raw materials, the cost of power and the casting itself, as to what it will cost per pound. But in general practice it has been found that there is a less number of losses in electric furnace castings than with the ordinary castings. I do not pretend to say what that is due to, whether a better state of the metal for that purpose, freedom from gases, etc., but that is the consensus of opinion among those using the electric furnace. I had a conversation a few weeks ago with the manager of a steel casting plant in Germany. He said they had six crucible furnaces shut down which they would never start up again, as they were using the electric furnace right along with satisfactory results. I cannot answer the question as to cost.

MR. N. W. STORER: I notice Mr. Bennie did not offer any encouragement for the use of the electric furnace at any place except where they have hydro-electric power. I believe that from the developments in steam turbines, gas engines, etc., we will before very many years be able to use power economically generated by this means. I know of one power plant in operation at the present time where the cost of power, generated by steam, is less than ¼c per kilowatt hour. It seems to me that power at anything near that range can be applied to the electric furnace. Of course in this case the cost of coal is extremely low as the plant is right at the mine. But there is no reason why power plants cannot be located at mines if there is a reasonable supply of water available. I believe that such power will be available in the near future.

THE AUTHOR: When I referred to hydro-electric power I referred to that for the production of pig iron, which has necessarily to be a low price material. But even with steam generated power with large units and most improved methods,

at about $22 per horse power year, you would have to go a long way with the electric furnace in proper condition to compete with pig iron under $15.

MR. N. W. STORER: How much does the cost of power at $15 a year add to it;

THE AUTHOR: The product is about 4 tons a horse power year. There is therefore ¼ of the difference. But the Swedish installation has power at $9.65, and the difference between that and $22 in a plant using 10 000 h. p. would make a handsome return.

So far as steel refining is concerned, where the power consumption will be somewhat under 250 k. w. hours per ton, even down to 125 k. w., you can make 70 tons of refined steel per horse power year. Then the matter of power, figuring the difference between 4 tons and 70 tons, becomes insignificant.

MR. J. W. TODD: What is the cost of electrodes in these large sizes?

THE AUTHOR: So far, about one dollar a pound. Practically the cost should be about the same per pound as for electrodes from ten inches to one inch diameter; it should not be any higher after the first research work is done. The trouble at present is two-fold. First, the difficulty of making very large electrodes because the apparatus with which to make them does not exist. Powerful hydraulic presses are required, and it takes about a year to build the plant to make electrodes say 20 inches in diameter. Second, there are other problems of raw materials, mixing and baking, the development cost of which have been high.

MR. J. W. TODD: What do they cost today?

THE AUTHOR: They cost about 4½ cents for the amorphous carbon kind, and Mr. Smith will tell you what they charge for theirs. I hesitate to tell. What is it, Mr. Smith?

MR. M. A. SMITH: About $11 per hundred pounds.

MR. A. STUCKI: I have heard statements that with the Héroult furnace we can get any degree of refining and we can

eliminate sulphur and phosphorous to any figure desired but if I understand Mr. Bennie right, you cannot do that with the induction furnace. On the other hand, I have heard it stated that this latter furnace will produce steel just as fine as we want it, phosphorous something like .015. I would like very much to know whether such is the case, and if not, just why. It looks very much as if the absence of any electrode in itself should compensate for a good many other things, save money and avoid particles of burnt carbon entering the bath.

The Author: When I said the induction furnace did not lend itself well to refining I was speaking of the simple induction furnace, having an annular crucible and with no open spaces on the side like the Rochling-Rodenhauser furnace, because in the latter case that is where the refining is done. The metal is circulated in the open places between the rings and the refining slag is contained there. One of the slides showed the degree of elimination of phosphorus, etc. using the Rochling-Rodenhauser furnace. So far as the simple induction furnace is concerned I think I said it was an efficient melting apparatus and should not be considered as a refining apparatus because the contact between the slag and the bath was such a small surface that very little refining could be accomplished there. But in the other types of induction furnaces that is not so.

Mr. H. W. Fisher: The paper is certainly a notable acquisition to our proceedings. I think we owe the author a vote of thanks for the care he has taken in preparing it. The paper gives us a splendid idea of the present statue of electrical furnace work. Therefore, I move that a vote of thanks be tendered to Mr. Bennie for his most interesting and valuable paper. The motion was seconded and carried by unanimous vote.

NECROLOGY

THOMAS HOUSTON CARLIN.

Allegheny, Pa., December 7th, 1851.

Allegheny, Pa., June 23rd, 1909.

He was the son of Thomas Carlin Sr. and Flora McMechan, being the second of five children. His father and older brother David, both deceased were members of the Society, and his brother John H. is a member at this time.

After his father's death he was senior member of the firm of Thomas Carlin's Sons, estabilshed in 1865, manufacturers of engines, boilers, contractors and rolling mill machinery. Mr. Carlin was an expert designer and foundryman, and designed and installed the machinery in many of the brick yards in Western Pennsylvania. He took out numerous patents, many of which marked a decided advance in their special fields.

He retired from active affairs in 1899, and after spending two years in traveling he returned to Pittsburgh, giving his attention to investments until stricken with paralysis in 1902, which rendered him practically helpless until his death in 1907.

On November 8th, 1886 he married Sarah Agnes Alexander, who survives him together with three children, Thomas H., William M., and Flora M.

WILLIAM H. SINGER.

Pittsburgh, Pa., 1835.

Watch Hill, R. I., September 4, 1909.

He was the son of George and Elizabeth Singer who came to this city from Greensburg, Pa. Before the age of 20 years he entered the employ of Shoenberger & Company, remaining with them for a number of years. About 1860 he entered the firm of Singer, Nimick & Company, which was organized by his brother. He at once became the controlling power in the company, being made president and remaining in that capacity until the company was merged with the Crucible Steel Company of America.

Mr. Singer was one of the organizers of the Homestead Steel Works and was president of the company until it was bought in by

the Carnegie Steel Company. He was at this time invited by Andrdew Carnegie to become one of the partners of the Carnegie Steel Company and he was a director of this company at the time of his death.

He was a director of the Bank of Pittsburgh, National Association, and at one time was a director of the Exchange National Bank. Mr. Singer was a prominent member of the Trinity Episcopal Church and he contributed largely to many charitable institutions, one of the chief beneficiaries being the Allegheny General Hospital.

Mr. Singer was one of the earliest members of the American Institute of Mining Engineers and his membership in the Engineers' Society of Western Pennsylvania dates from the year of its charter.

Mr. Singer was injured in an automobile accident at Matunuck, Rhode Island, on August 25, 1909, and was unconscious practically all of the time until his death, ten days later at his summer house in Watch Hill, R. I.

He is survived by his widow, Mrs. Hester Harton Singer, and four children, George Harton Singer, Mrs. Robert Milligan, of Pittsburgh, and Mrs. William Ross Proctor, of New York.

GEORGE THOMAS BARNSLEY.

Montgomery County, Pa., January 23, 1864.

Pittsburgh, Pa., October 23rd, 1909.

After early education in public and private schools he entered Swarthmore College taking a course in civil engineering. His first work was with the Norfolk and Western Railway Company, and after remaining with that road six years, he took a position with the Pennsylvania Railroad Company. His work with this and other roads gave him wide experience and in 1901, when the Wabash System sought an entrance into Pittsburgh, he was made resident engineer in charge of the Pittsburgh Terminal of that organization. Later he was made chief engineer of the lines of the Wabash System east of Toledo, resigning this position in October 1905. While in these positions he superintended the construction of the cantilever bridge over the Monongahela River, the Wabash Depot and the Duquesne Way improvements.

In January, 1906, he became Road Engineer for Allegheny County, and his plans for this work contemplated the macadamizing of 600 miles of the 1750 miles of county roadway.

He was President of the Society at the time of his death, and was also a member of the American Society of Civil Engineers, the

Engineers' Club of Philadelphia, The Franklin Institute, The American Association for the Advancement of Science, and The Art Society of Pittsburgh.

He was stricken with heart failure while at his desk, and died at 11:30 just two hours prior to the time set for an inspection trip by the Society to the new P. & L. E. R. R. Bridge over the Ohio River at Beaver, Pa. Members of the Society were already assembled at the Railroad station when Mr. Barnsley's death was announced and the trip was abandoned.

Mr. Barnsley was one of the most active members the Society has had in recent years and was most prominent in his work in connection with the Entertainment Committees of the Society which had charge of inspection trips, etc.

He had a host of warm friends, his kindly and earnest manner winning them rapidly and holding them. He took a keen interest in the younger members of the Society, and was always ready and willing to assist them.

The funeral services, held in Trinity Church, were attended by members of the Society in a body and a Committee represented the Society at the interment in Rock Creek Cemetery in Washington, D. C.

Mr. Barnsley was married in 1890 to Susan G. Jones of Olney, Mo., and is survived by her and a son, George T., Jr.

CHARLES B. DUDLEY.

Oxford, N. Y., July 14, 1842.

Altoona, Pa., December 21, 1909.

His early years were spent at the village school and in working on a farm in summer. In 1862 he enlisted in the 114th New York Volunteers and spent nearly three years in the army, being finally severely wounded on September 19, 1864.

Returning from the war in 1865 he prepared for college, entering Yale and graduating in 1871. A year later he began a two years' course in chemistry in the Sheffield Scientific School, graduating in 1874. He spent a year as instructor in the University of Pennsylvania and in November, 1875, he accepted the position as Chemist of the Pennsylvania Railroad Company at Altoona, which position he held until his death, thirty-four years later.

That part of his work which attracted the most wide-spread attention, was the study of steel rails in the early eighties and his re-

searches made a deep and lasting impression on the metallurgical world.

His part in the preparation of Pennsylvania Railroad specifications was most important and while chemistry was not the only factor in these specifications, yet his wide experience and clear insight enabled him to assist others largely in the preparation of the physical requirements. His work in connection with the solution of passenger car ventilation attracted world wide attention.

It would be difficult to name an engineer who has had a greater or more varied experience in the testing of materials than Dr. Dudley, and he stood as the highest representative type of the testing engineer with a world wide reputation for integrity, skill and rare judgment, and a richly deserved reputation for unselfishness.

He became a member of this Society in April, 1892, and presented several important papers at its meetings. He was twice president of the American Chemical Society, and was president of the American Society for Testing Materials. He was a member of

The American Society of Civil Engineers,
The American Society of Mechanical Engineers,
The American Institute of Mining Engineers,
The American Institute of Electrical Engineers,
The English, French and German Chemical Societies,

and a large number of other Societies both in this country and abroad.

He made many important contributions to the Proceedings of various technical Societies and gave freely of his time in connection with the Mechanics Library of Altoona.

He was married on April 17th, 1906, to Miss Mary V. Crawford, who survives him.

FREDERICK GWINNER.

Allegheny, Pa., 1856.

Pittsburgh, Pa., April 27th, 1910.

He attended the University of Western Pennsylvania, graduating in the engineering school, and when 21 years old was admitted to the firm of Frederick Gwinner & Company, which had been founded by his father.

He was well known in business circles in Pittsburgh, having continued the contracting business established by his father. He was president of the Allegheny Traction Company, and was a director of the Allegheny Trust Company, The Pittsburgh Brewing Company, The National Fireproofing Company, The Peoples Natural Gas

Company, The Pittsburgh Casualty Company and the Volksblatt Publishing Company.

Mr. Gwinner became a member of the Society in September 1882. He is survived by one brother, Edward.

JEAN A. THORSELL.

Palmer, Sweden, 1855.

Pittsburgh, Pa., May 5th, 1910.

He was graduated from the engineering school of the University of Stockholm and shortly after came to this country. In 1886 he entered the employ of William Scaife & Sons Company, and continued his services with the company as chief engineer up to the time of his death.

He resided for many years in Bellevue and was a prominent member of the Bellevue Presbyterian Church.

He became a member of the Society in April, 1889. He is survived by his wife, two sons, Jean Jr., and Roff E., and one daughter, Jane C.

WILLIAM METCALF.

Pittsburgh, Pa., 1838.

Pittsburgh, Pa., December 6, 1909.

William Metcalf was born in the old Metcalf homestead in Fulton Street, now occupied by the Kingsley House. His early education was obtained in the public schools and at the age of 20 was graduated from the Rensselaer Polytechnic Institute in the class of '58. Returning to Pittsburgh he entered the employ of the Fort Pitt Foundry, then one of the most famous gun foundries in the world. During the Civil War he was superintendent of the foundry and had charge of the manufacture of the 15 inch and 20 inch cannon which were so largely used by the Union forces.

In January 1868 he formed the partnership of Miller, Barr & Parkin for the manufacture of crucible steel. In 1870 the firm became Miller, Metcalf & Parkin, and through Mr. Metcalf's skill and high reputation as an engineer their brands of steel became known all over the world. In 1886 the firm was incorporated as the Crescent Steel Company, which later became a part of the Crucible Steel Company of America. Mr. Metcalf retired from the firm in 1895 and organized his own company the Braeburn Steel Company and in 1897 erected a most modern plant for the manufacture of crucible steel at Braeburn.

Mr. Metcalf was one of the organizers of this Society, a charter member, its first president, and read the first paper before it on

January 20th, 1880, the subject being "Why does Steel Harden?" which attracted wide attention.

He was president of the American Institute of Mining Engineers in 1880 and in 1893 was made president of the American Society of Civil Engineers. He was Vice-President of the American Society of Mechanical Engineers from 1882 to 1884. He was also a member of the Institution of Civil Engineers of Great Britian, and the Engineers Club of New York. He was a charter member, and at one time president of the Duquesne Club. For many years he was a vestry man, and at the time of his death senior warden of St. Peter's Protestant Episcopal Church. He wrote several books on steel which are regarded throughout the world as standard works, and his numerous papers on the same subject before this and other societies were widely read.

Mr. Metcalf was chairman of the board of arbitration which settled the problems incident to the freeing of the Monongahela River. He and two other prominent Pittsburgh men were appointed by the government to take all evidence in the matter and their decision was final.

In 1864 Mr. Metcalf was married to Miss Christina Bager Fries. His wife and six children survive him: Charles, Mrs. W. G. Doolittle, William, Jr., Mrs. Henry Tod, Mrs. George H. Neilson, Orlando Paul, and also 14 grand children and one sister, Mrs. Mary Bruce of Santa Monica, California.

THOMAS WOODHOUSE BAKEWELL.

Allegheny County, Pa., October 27, 1861.

Pittsburgh, Pa., July 7th, 1909.

He was born at "Sunnyside," McClure Township and his boyhood was spent at Arnold Station, Pa., his father's home. He was educated at Rutger's College, graduating with second honors in his class, and then entered the Law School of the University of Pennsylvania. After graduation he entered his father's office, and was admitted to the Allegheny County bar, November 27th, 1883, becoming a member of his father's firm, William Bakewell & Sons, patent attorneys at the same time.

Mr. Bakewell later became associated with John R. Bennett, leading counsel for the United States Steel Corporation, and following Mr. Bennett's death Mr. Bakewell took his place as counsel for many great New York corporations being chairman of the Patent Committee of the United States Steel Corporation. From the inception of the mechanical blowing of window glass he was retained as chief counsel by the American Window Glass Company all of whose patents were taken out through Mr. Bakewell. He was general counsel for

the Westinghouse Air Brake Company, the Union Switch & Signal Company, The American Locomotive Company, The United Gas Improvement Company, The Welsbach Light Company, The Aluminum Company of America, The Carborundum Company, as well as many other large corporations.

While he had a national reputation in patent law and his counsel was widely sought yet he had a very retiring manner, and was most marked in his courteous and considerate relations with all. He was untiring in his devotion to his business in which his high ideals were evinced by the character of his daily work. Shortly after his admission to the bar he was married to Annie Bakewell King, daughter of Dr. Cyrus B. King of Allegheny, by whom he is survived, in addition to two children Euphemia and Allan Campbell.

REESE JAMES.

Pontypool, Wales, April 20, 1850.

Pittsburgh, Pa., December 30, 1910.

Mr. James, in his thirteenth year, came to the United States with his parents who settled at Johnstown, Pa. He entered the steel business as a young man in Johnstown, and later went to Pueblo, Col. In 1890 he went to Braddock, Pa., being employed at the Edgar Thomson Steel Works.

In 1892 Mr. Charles M. Schwab, who was then general superintendent of the Homestead Steel Works, recognizing his marked ability called Mr. James to the Homestead Works, making him superintendent of the structural department and the 10-inch mill.

After the formation of the United States Steel Corporation Mr. James was made superintendent of the bessemer department of the Homestead Steel Works in 1902. In 1905 he became superintendent of the open hearth department of these works, including mills No. 1, 2, 3 and 4.

His interests were closely centered in his home, and all who entered it felt its delightful charm. He was untiring in his business which ever called forth his best efforts, and the success he obtained attests his marked ability. He was of a most genial temperament and enjoyed a large circle of friends. He spent much time in his library, as he read extensively. His charities, while large, were most unobstrusive, and he was ever ready to help the unfortunate.

He is survived by his widow and three children; Edgar, Evelyn and Althea James, also two brothers and four sisters; Thomas James, former superintendent of the Edgar Thomson Steel Works, Morgan James, of Lorain, Ohio, Mrs. Agnes Platt, of Munhall, Mrs. John Apel, of Braddock, Mrs. Bessie Gard and Mrs. William Thomas, of Johnstown, Pa.

ABSTRACT OF MINUTES

FEBRUARY 1910 TO JANUARY 1911

ABSTRACT OF MINUTES

Engineers' Society of Western Pennsylvania

1910

ANNUAL MEETING.

The Thirtieth Annual Meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, January 18, 1910, at 8:10 P. M., President Morse presiding, 55 members and visitors being present.

The minutes of the last annual meeting, held January 19, 1909, were read and approved.

The annual report of the Board of Directors, including the reports of Standing Committees, Sections and the Treasurer, was read, as follows:

REPORT OF THE BOARD OF DIRECTION.

The Board of Direction held thirteen meetings during the past year, at which the routine business of the Society was transacted. Certain bond investments recommended by the Finance Committee were made from the General Fund of the Society.

Pursuant to a request made by the Alumni Association of Columbia University in Pittsburgh, a candidate for a free scholarship in the University was presented to the local Alumni Association. This candidate was awarded the scholarship and is now doing good work in the University.

A memorial letter was sent to the Aero Club of America in connection with the presentation of medals to the Wright Brothers, in which suitable mention was made of the pioneer work done in aerodromics by Prof. Langley, a former member of this Society.

During the year there were held eight regular, one special and the annual meeting of the General Society. The average attendance was 68, and the average number participating in discussion of papers, eight. The maximum attendance was 121 and the minimum 40.

There has been a notable increase in the attendance at the Section meetings during the past year, the average attendance of the Mechanical Section increasing from 36 to 60, and of the Structural Section from 34 to 61.

At the close of the year the membership of the Society stood as follows:

Honorary members	6
Life members	3
Active members	799
Associates	5
Juniors	22
Total	835
During the year there were:	
Resignations	41
Removals by death	10
Dropped	3
Total	54
Accessions	59

The net increase in membership for the year is five.

ELMER K. HILES, Secretary.

REPORT OF HOUSE COMMITTEE.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

During the past year the Auditorium has been used on 51 occasions, 20 times for Society meetings and 31 times for other Societies.

The Society rooms have been open every Saturday night until 10 o'clock, the total attendance being 76. It is the belief

of this Committee that much good would result if smokers were held in the Society rooms on one Saturday night in each month.

Respectfully submitted,

S. A. TAYLOR, Chairman.

REPORT OF PUBLICATION COMMITTEE.

To the Board of Direction of the Engineers' Society of Western Pennsylvania:

On behalf of the Publication Committee I have the honor to report as follows for the year 1909:

The Publication Committee has, during the year, held monthly meetings and arranged for the program for the general meetings of the Society. Papers have been provided for each of these meetings. So far as the control of the Proceedings is concerned, the publication during the past forms the record of the work. The publication has been carefully edited by the Secretary, and by means of careful preparation of copy for the printer it has been possible to reduce materially the charges for corrections in proof.

During the year there has been considerable discussion of the relation of the Sections to the General Society, and as the principal point involved was that of the programs, this Committee has studied the question carefully. The Committee believes that an addition to its members of representatives of the Sections and the delegation to it of all questions of program would promote a more harmonious inter-relation of the various branches of the Society. Such an arrangement is provided for in the new by-laws now before the Society, which were proposed by the Committee appointed to study the general question. In this connection it is a pleasure to record the fact that in all endeavors to adjust these questions the officers of the Sections have considered all points in a broad spirit and have worked with us most harmoniously to ensure the best results for the Society.

As a result of its experience the Committee believes that the Society suffers from the fact that the new program committee, appointed at the beginning of the year, starts a bank-

rupt as regards program. It would be much better if the Committee appointed in February should find the program filled for some months. To make a trial possible, we have filled the programs, both sectional and general, until June, 1910. This will allow the incoming committee to arrange a program for the sessions from September, 1910, to June, 1911, without doing more than a normal year's work. We believe that the six months of time available in which to make plans, before any meetings must be provided for, will make it possible to secure better papers and a more coherent program.

The Committee wishes to record the unusually efficient help which it has received during the year from the Secretary.

Respectfully submitted,

HARRISON W. CRAVER, Chairman.

REPORT OF THE MECHANICAL SECTION.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

During the past year five meetings of the Mechanical Section were held. The average attendance was 60, and the average number participating in discussions, eight. The maximum attendance was 71, and the minimum, 48.

The attendance shows a healthy increase, the average attendance being nearly double that of the last report.

Respectfully submitted,

RICHARD HIRSCH, Chairman.

REPORT OF THE STRUCTURAL SECTION.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

During the past year five regular meetings were held, at which four papers were presented and one topical discussion. The average attendance was 61, and the average number taking part in the discussion, nine. The maximum attendance was 81 and the minimum, 41. The following subjects were presented:

(1) At the January meeting Mr. E. W. Pittman read a paper on, "Secondary Stresses in Framed Structures."

(2) At the March meeting Mr. S. E. Duff presented a paper on, "Some Observations on Shop Management."

(3) At the May meeting Mr. R. B. Woodworth presented a paper on, "The Steel Oil Derrick."

(4) At the September meeting a discussion on "Contracts with Special Relation to Structural Steel" was presented by the Chairman, Attorneys Watson B. Adair, H. M. Stilley and S. A. Schreiner, also Messrs. O. M. Topp, V. R. Covell, L. J. Affelder and Edward Godfrey.

(5) At the November meeting a paper was presented on, "Gas Holders" by Mr. Louis Vincent.

The subjects presented during the year have been of more than ordinary value and interest. This has shown itself in the increased attendance, the average for the year being nearly double that of last year.

It is to be regretted that there has been circulated during the past year some adverse criticism of the Sections, based on a misconception of the purposes for which they are organized and a misunderstanding of the relations which have existed between them and the Publication Committee.

The programs of the Structural Section have in all cases been submitted to the Publication Committee in advance, and, except in one instance in which a change was made at the Committee's suggestion, were approved as submitted. With the concurrence of Mr. Craver, Chairman of the Publication Committee, the statement is made that in every instance the utmost harmony and good feeling prevailed.

The increased interest in the meetings of the Section and general worth of the papers contributed are evidences of the prosperity of the Society, and show the advantage of an organization whereby the Society can benefit from the active cooperation of members in the same branches of our profession.

As intended and stated in the by-laws of the General Society, we feel that we are part and parcel of the General Society, and that the successful work of the Section reflects to the credit of the Society as well as the Section.

We note that the Western Society has recently organized

a Bridge and Structural Section corresponding to our Structural Section.

It is not sufficient that the standing of the Society and its Sections and the reputation of its publications should be maintained, but every effort should be made to secure papers of great permanent worth and reference value, and active interest should be taken in every live engineering question, especially those affecting this community, so that the Society may achieve that high standing and reputation which are possible with its present membership and organization.

If necessary, a program should be mapped out and men selected to suit the program, or possibly committees selected to investigate certain subjects, as is done in some of the railroad organizations, and their result given as reports. This line of work is well suited to the Sections where the subjects are limited to a certain range.

We believe that the topical announcements have attracted many to the meetings, and heartily commend this policy.

At the annual meeting held January 4, 1910, the following officers were elected for the ensuing year:

Chairman—V. R. Covell.

Vice Chairman—R. B. Woodworth.

Directors—W. B. Miller, S. E. Duff, L. Vincent.

Respectfully submitted,

J. A. McEwen, Chairman.

REPORT OF TREASURER.

To the Board of Direction, Engineers' Society of Western Pennsylvania:

INVESTMENTS

Building Fund

One, $1,000 00 Butler Water Company, 6 per cent. bond, No. 9, matures September 2, 1931..... $ 1.025 00

Permanent Fund

Two, $1,000 00 Connellsville Water Company, 5 per cent. bonds, Nos. 317-318, mature October 1, 1939..... 2.020 00

Two, $1,000 00 Portsmouth, Berkeley & Suffolk Water Company, 5 per cent. bonds, Nos. 465-466, mature November 1, 1944	2,000 00
One, $1,000 00 Manufacturers Light & Heat, 6 per cent. bond, No. 4266, Series K, matures May 1, 1914	1,010 00
One, $1,000 00 Jones & Laughlin Steel Company, 5 per cent. bond, No. 3020, matures May 1, 1931	999 30

General Fund

Two, $1,000 00 Jones & Laughlin Steel Company, 5 per cent. bonds, Nos. 3021-3022, mature May 1, 1931	1,998 62
Total nine bonds	$ 9,052 92

RECEIPTS.		EXPENDITURES.	
Dues, 1910	$ 42 50	Administration	$ 3,035 17
Dues, 1909	5,809 70	Entertainment	862 10
Dues, 1908	265 00	House	2,570 21
Dues, 1907	48 00	Library	128 55
Advance Payments	190 00	General Society	781 29
Entrance Fees	320 00	Mechanical Section	87 45
Advertising	1,819 18	Structural Section	127 37
Interest	550 63	Proceedings	2,110 85
Banquet	857 50	Advertising	36 70
Sale of Proceedings	467 96	Miscellaneous Printing	208 25
Sale of Cuts	23 50	Miscellaneous	35 00
Sale of Slides	20 00		
Society Pins	16 50		
Rent of Auditorium	113 00		
	$10,543 47		$9,982 94

TOTAL ASSETS

	December 31, 1908.	*December* 31, 1909.
Bonds	$7,065 00	$ 9,052 92
Permanent Fund	1,532 17	1,591 44
Building Fund	491 55	510 55
General & Petty Cash Funds	1,734 93	219 27
	$10,823 65	
Increase in Assets for 1909 over 1908	550 53	
	$11,374 18	$11,374 18

Respectfully submitted,

A. E. FROST,
Treasurer.

The canvass of ballots cast in the annual election was reported by the tellers, Messrs. V. R. Covell, G. H. Danforth and W. M. Judd, as follows:

E. K. Morse for President	209
J. O. Handy for Vice President	206
A. E. Frost for Treasurer	209
A. R. Raymer for Director	207
Willis Whited for Director	207
Blank Ballots	10
Unsigned Ballots	1
Rejected Ballots	4

The above named officers were declared duly elected.

The President-elect greeted the Society in the following address:

Gentlemen of the Society: I regret exceedingly that I cannot be received here as the next President of the Society by our Past President Mr. George T. Barnsley, as there is nothing that would give me greater pleasure than to have him extend to me the right hand of fellowship. I do not expect in the year before me to fill this position with the energy that Mr. Barnsley did, though there are some features concerning the welfare of this Society that I wish to take up, and throw into the work my best energies.

It is a surprise to me to learn by the Secretary's report this evening that our net growth during the past year is only five members. There are many capable engineers in this City, and its immediate vicinity, whose membership would be an honor to the Society, and whom I am sure would be greatly benefited if they were active members. It is my intention to take up with the Directors at an early date the advisability of creating a new committee on membership. In my desire to see the membership greatly increased I assure you it will not be at the expense of the standing of the new members, which I hope will be more and more representative as the years pass.

A new condition has developed—especially during the last six months—that vitally interests this Society, which I believe is to quite a large extent to blame, and perhaps excuses the civic

bodies and the Mayor of Pittsburgh for going out of our midst for engineering advise which could be abundantly furnished from home talent of just as high standing,, who would report in just as short a time and for one-half the expense that outside talent is providing and being paid for at present. It is claimed that the outside talent is expert engineering for specific purposes. Did our Mayor serve an apprenticeship? Certainly not and he is making good. We have in our midst an attorney of national repute,—does anyone doubt his ability to take a case new to him? Emphatically, no! The fact that he will consent to take the new case is all that concerns the client. There are times and cases where it is to the distinct advantage of all concerned to have outside help, but that only in an advisory way and in order to get started right and in the shortest possible time. Just so long as this Society lies dormant, its moral force will not be felt in the way that it should be, and would be if we would waken up as individuals and as a body to the conditions that now exist on all sides. If you feel safe in giving me your support as individuals and as a Society I believe the moral force of this Society will become a power and be felt even if it becomes necessary, not as a Society but as united individuals, to go to the precincts and work for the best good to our City and State.

Gentlemen, I appreciate the honor you have conferred upon me; it would not be natural if I did not. And I appreciate it especially because I have not pulled one wire to get here—and I have been a good while getting here. Perhaps because that has been longer deferred than with some others, I think I appreciate it just that much keener. Certainly my appreciation is keen and genuine and I sincerely thank you, and I am glad to notice that the vote was unanimous.

No further business coming before the Society Mr. E. K. Morse addressed the Society on "The Erection of the Hawkesbury River Bridge" showing about 75 lantern slides illustrating special features of the work.

The meeting adjourned at 10:15 P. M.

ELMER K. HILES, Secretary.

STRUCTURAL SECTION.

The annual meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday evening, January 4 ,1910, at 8:20 P. M., Chairman J. A. McEwen presiding, 122 members and visitors being present.

The minutes of the last Annual Meeting, held January 5, 1909, were read and approved.

The Nominating Committee, composed of Willis Whited, T. J. Wilkerson and W. M. Judd, reported the following nominations:

Chairman—V. R. Covell.

Vice Chairman—R. B. Woodworth.

Directors—S. A. Duff, W. B. Miller, Lewis Vincent.

No other nominations being made the above-named members were elected unanimously.

The retiring Chairman addressed the Section with the following remarks:

"I wish to thank the members of the Executive Committee for the help they have given me in getting papers and in the other work of the Section, and also the members in general for the interest they have taken in the Section during the past year.

"One thing which has been of great help to the Section is the topical announcements arranged by the Secretary. These have been a great factor in getting members to the meetings and I think should be commended.

"There has been some little difficulty, possibly more imaginary than real, in regard to the relative standing of the Sections and the Society at large, and I want to mention one thing in connection with that especially. Article VIII., Section 6, specifically states that the Section shall be a part and parcel of the General Society, and in anything which comes up in connection with the Sections we should not fail to have this fact in mind. It will help to avoid a further misunderstanding on this subject. I think, however, there ought to be a unity of action between the Sections and the General Society. I am

sorry that the Chemical Section has been lost to the Society, as the chemist is the engineers' great ally. The Sections are undoubtedly a great source of strength in the upbuilding of the Society and they should be encouraged.

"In regard to programs we have as a matter of necessity had quite a variety of subjects. I believe it would be a good plan if we could arrange through the Publication Committee to lay out a program and invite certain engineers to discuss the subjects, or, if necessary, refer these subjects to committees for investigation and report. The work of the Society should stand for more in the community than at present. Engineers as a rule are men who do much and say little. This Society is surely a representative body of the engineers in this end of the State, and our Proceedings should become even more of a work of reference. This can be accomplished more readily in the Sections than in the General Society, where all manner of topics come up for discussion. Our topics, as discussed, are valuable for reference and should stand for the expression of the engineers of this section of the state.

"This has been called an age of commercialism, but it can be more truly said that it is an age of the engineer because of the monumental things which have been and are being accomplished through the efforts and skill of the engineer. The work of the engineer surely stands pre-eminent. The great railway bridges and tunnels, the monumental office buildings, these things will remain when the spirit of commercialism has largely disappeared.

"There is one thing which I believe is giving the engineers more trouble than anything else, and that is the preservation of steel. We hear a great deal in these days about paint and preservatives, and we hear so many things that we do not know what to call the best. Possibly the preservation of steel will be worked out through the quality of the material itself. We have heard quite a little of nickel steel, and we are hearing today of aluminum-coated steel especially for the sheet metals, and also copper-coated, and possibly this is the working out of the preservation of steel. Steel is one of the materials which can be used for the building of great structures such as bridges,

but the preservation of it is a very serious thing, and to my mind one of the greatest problems the engineer has before him."

Mr. Willis Whited was requested to conduct the Chairman-elect, Mr. V. R. Covell, to the chair, who said:

"I realize that a very difficult line of duty has been laid out for me in following one who has been as successful and untiring in his efforts as Mr. McEwen, and yet with your assistance I will endeavor to make the work of the Section for the coming year just as profitable and helpful as it can possibly be."

There being no further business, the Annual Meeting was adjourned at 8:40 P. M.

The regular monthly meeting was called to order by Chairman Covell at 8:41 P. M.

The minutes of the last regular meeting were read and approved.

The paper of the evening on "The Masonry for the Ohio River Bridge of the P. & L. E. R. R. at Beaver, Pa.," was presented by A. R. Raymer.

The ensuing discussion was participated in by Messrs. R. T. McMasters, J. J. Nolan, J. H. Toupet, G. L. Taylor, Willis Whited, C. P. Buchanan, T. H. Johnson, J. P. Leaf, Herman Laub, H. J. Lewis, Edward Godfrey, W. F. Hall, H. S. Prichard and A. R. Raymer.

The meeting adjourned at 10:30 P. M.

ELMER K. HILES, Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Friday, January 7, 1910, at 5:00 P. M., President Morse presiding, Messrs. Riddle, Frost, Schellenberg, Handy, Chester and the Secretary being present.

The minutes of the meeting held December 10, 1909, were read and approved.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board on November 5, were duly elected to membership:

ACTIVE

Edward Jay Billings, John Dickson Stevenson.

ASSOCIATE

Homer B. Melat.

JUNIOR

Rowland Lawrence Young.

Applications of the following gentlemen were received and their names ordered published to the Society:

ACTIVE

James Brennan, Wm. F. Hall,
Thomas Duckworth, Jonathan Jones,
G. L. Taylor.

JUNIOR

Frank S. McClintock.

The Secretary announced the death of Dr. C. B. Dudley on December 21, 1909, who joined the Society in April, 1892.

The Secretary read a card from Mrs. Metcalf, acknowledging the expression of sympathy sent by the Society.

The report of the Secretary showing the financial condition of the Society at the close of business December 31, 1909, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The following resolutions were presented by the Secretary:

IN MEMORY OF WILLIAM METCALF,
WHO DIED DECEMBER 5, 1909.

WHEREAS, The Engineers' Society of Western Pennsylvania has been deprived by death of the companionship of William Metcalf, and

WHEREAS, He was one of the founders of the Society, its first and second President, and the author of the first paper in its Proceedings; be it

RESOLVED, That this Society record its high appreciation of the deep interest he held in it and his valued advice through-

out the thirty years of its existence, his eminent attainments and his masterly discussions of the many topics proposed for consideration at its meetings. He was an earnest, true friend, wise in counsel charitable in judgments,, quick and kindly in his sympathy for all who appealed to him. We shall miss our esteemed associate, personal companion and friend, but will always treasure the memory of his association with us.

Respectfully submitted,

THOS. H. JOHNSON,
JOHN A. BRASHEAR,
GEO. S. DAVISON,
Committee

The Secretary was requested to prepare a memoir of Mr. Metcalf to be published in the Proceedings with the above resolutions.

The Chairman of the Entertainment Committee, Walther Riddle, reported that arrangements had been made for holding the Annual Banquet of the Society on Saturday, January 29, at the Fort Pitt Hotel.

The meeting adjourned at 5:45 P. M.

ELMER K. HILES, Secretary.

REGULAR MONTHLY MEETING

The 299th regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Fulton Building, Pittsburgh, Tuesday, 15 February, 1910, at 8:19 P. M., President Morse presiding, 96 members and visitors being present.

The minutes of the last meeting, held 16 November, were read and approved.

The following amendments to Article II, Section 10; Article V, Section 13, and Article VI, Sections 4 and 7, of the By-Laws of the Engineers' Society of Western Pennsylvania, having been presented to the Board of Direction, were read before the Society:

ARTICLE II.

Section 10. A member of any grade in the Society may resign his membership by a written communication to the Board of Direction, provided he is in good standing and all dues to the Society are paid to the end of the current calendar year.

ARTICLE V.

Section 13. In case of death, or resignation of an officer of the Society, the Board of Direction shall fill the vacancy, except as provided in Section 12 of this Article. In case of the disability of, or neglect in the performance of any duty by, an officer of the Society, or absence from three successive meetings of the Board of Direction by a member thereof, without sufficient excuse, the Board may declare the office in question vacant and fill same, except as provided in Section 12 of this Article.

ARTICLE VI.

Section 4. The following standing committees shall be appointed to serve for one (1) year: Finance, House, Publication and Entertainment. The Chairman of each of these committees shall be chosen from among the members of the Board of Direction, and each committee shall consist of at least three (3) members, all to be appointed by the President, by and with the advice of the Board of Direction, except that the Publication Committee shall, in addition to the members so appointed, further consist of the Chairman of each Section of the Society. These committees shall report to the Board of Direction, and perform their duties under its supervision. They shall neither make expenditures nor contract any obligations for the Society, without

the consent of the Board. The Chairman of each Committee shall personally examine and vouch for all bills of his committee.

Section 7. The Publication Committee shall have charge of the editing and publishing of the Proceedings. It shall also have charge of the programs of the meetings of the Society and its Sections and shall have full jurisdiction with regard to all papers and topics to be presented or discussed.

On motion these amendments were approved and ordered submitted to the Corporate Members of the Society, in accordance with Article IX of the By-Laws.

No further business coming before the meeting, the paper of the evening on "The Government Testing Station in Pittsburgh," was read by Mr. J. C. Roberts, Asst. Chief Engineer of the Technologic Branch of the U. S. Geological Survey.

The ensuing discussion was participated in by Messrs. Schellenberg, Taylor, Hiles and Roberts.

A vote of thanks was extended to Mr. Roberts for his very interesting paper.

Adjourned at 10:25 P. M.

ELMER K. HILES, Secretary.

MECHANICAL SECTION

The Annual Meeting of the Mechanical Section of the Engineer's Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, February 1, 1910, at 8:15 P. M., Chairman Richard Hirsch presiding, 30 members being present.

The minutes of the last Annual Meeting were read and approved.

The report of the Nominating Committee was presented by J. L. Klindworth, Chairman of the Committee as follows:

Chairman, A. Stucki

Vice Chairman, Geo. K. Smith

Directors

W. C. Hawley O. L. Gerwig

L. C. Moore

On motion the Secretary was requested to cast a unani-

mous ballot for the gentlemen nominated, who were thereupon declared elected.

The Chairman elect then took the chair and the minutes of the last regular meeting were read and approved.

The address of the Retiring Chairman, on "The Engineers' Society—Its Future," was presented by Mr. Hirsch.

The ensuing discussion was participated in by Messrs. Morse, Schellenberg, Handy, Hiles, Flanagan, Gerwig, Whitman, Smith, Cavalier, Martin and Allison.

The meeting adjourned at 10:20 P. M.

ELMER K. HILES, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in Parlor D of the Fort Pitt Hotel, Pittsburgh, Friday, 11 February, 1910, at 7:45 P. M., President Morse presiding, Messrs. Handy, Craver, Grace, Chester, Raymer, Whited, and the Secretary being present.

The minutes of the meeting held 7 January were read and approved.

The applications of the following gentlemen having been regularly published to the Society pursuant to the action of the Board on 7 January, were duly elected to membership:

Active

James Brennan, Wm. T. Hall,
Thomas Duckworth, Jonathan Jones,
G. L. Taylor.

Junior

Frank S. McClintock.

Applications of the following gentlemen were received and their names ordered published to the Society:

Active

Per Halmar Schedin, Henry E. Cole.

The report of the Secretary, showing the financial condition of the Society at close of business 31 January, 1910, hav-

ing been previously audited by the Finance Committee, was approved and bills ordered paid.

The Secretary stated that Mr. Lehman of the office of the Fulton Building, had secured Mr. Phipps' approval of continuing to rent the present quarters to the Society on the same terms as heretofore.

The Secretary further made certain recommendations regarding the Auditorium of the Society with a view of obtaining more seating capacity. This matter was referred to the House Committee with request that their recommendations be made to the Board at its next meeting.

Announcement was made of the appointment of the following gentlemen as Chairmen of the Standing Committees:

S. P. Grace, Chairman, Entertainment Committee.
J. N. Chester, Chairman, Finance Committee.
S. A. Taylor, Chairman, House Committee.
H. W. Craver, Chairman, Publication Committee.

The matter of a Membership Committee was introduced for discussion, and President Morse was requested to appoint such a Committee to take up the work along the lines outlined by the Secretary.

Elmer K. Hiles was re-elected Secretary of the Society for the ensuing year.

The Secretary reported that a meeting of the General Committee on State Code for Engineers, composed of representatives from the Engineers' Club of Philadelphia, the Engineers' Society of Pennsylvania, the Scranton Engineers' Club, and the Engineers' Society of Western Pennsylvania, was held in Philadelphia on Saturday, 5 February. An organization was effected by the election of F. Herbert Snow as Chairman, and Elmer K. Hiles as Secretary. After discussion of the general subject, the meeting was adjourned subject to call of the Chairman.

A vote of thanks was extended to President Morse by the Board, expressing their appreciation of the entertainment at dinner previous to the Board meeting.

The meeting adjourned at 10:20 P. M.

A special meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Fulton Building, Monday 28 February, at 5 P. M., in response to the call of President Morse to consider the matter of removing the Society quarters from the Fulton to the Oliver Building.

The Past Presidents of the Society, together with the members of the House Committee, were invited to meet with the Board of Direction in consultation. President Morse presided. Messrs. Handy, Lyons, Whited, Raymer, Covell, Lewis, Albree, H. W. Fisher, Chalfant, Wilkerson and the Secretary being present.

President Morse announced that in view of the present cramped quarters in the Society's auditorium, it had been considered advisable to take up the question of either changing the partitions in our present rooms, or moving to another building.

The Secretary exhibited several sketches showing tentative changes in our present quarters, and also a layout of space offered to the Society on the 25th floor of the Oliver Building in the Sixth Avenue wing. The matter of space that would be needed was discussed, and Past President Chester B. Albree, President E. K. Morse and the Secretary were authorized to secure quarters for the Society on the 25th floor of the Oliver Building which floor has a 17 foot ceiling.

The meeting adjourned at 6:10 P. M.

ELMER K. HILES, Secretary.

REGULAR MONTHLY MEETING.

The 300th regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, 15 March, 1910, at 8:00 P. M., President Morse presiding, 50 members and visitors being present.

The minutes of the last meeting, held 15 February, were read and approved.

President Morse announced that the Chamber of Commerce of Pittsburgh, had requested the Society to appoint a committee to report on the question of the advisability of raising the bridges over the Allegheny River in Pittsburgh and stated that the Board of Direction had recommended the appointment of a disinterested committee of five, consisting of

Julian Kennedy,
James K. Lyons,
John N. Chester,
F. L. O. Wadsworth.
Emil Gerber,

to investigate this matter.

On motion of W. G. Wilkins, President Morse was requested to formally appoint the gentlemen named on such a committee.

The Secretary announced that very late in the afternoon of the day previous, he had received a telegram from Dr. W. H. Tolman, Director of the Museum of Safety and Sanitation, New York City, in reply to a message sent to him, stating that he had canceled his engagement to present his paper on "Industrial Safety and the Prevention of Accidents" some time before on his engagement book.

As Dr. Tolman failed to advise the Society of his action, the matter is unintelligible and his telegrams are very unsatisfactory.

The Secretary further announced that Mr. Thomas P. Roberts had kindly agreed, though on extremely short notice. to fill the program with a paper on "Floods in the River Seine."

The ensuing discussion was participated in by Messrs. Knowles, Chester, Cummings, Morse and Roberts.

The meeting adjourned at 9:10 P. M.

ELMER K. HILES, Secretary.

STRUCTURAL SECTION.

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, 1 March, 1910, at 8 P. M. Chairman V. R. Covell presiding, 40 members and visitors being present.

The minutes of the last meeting 4 January 1910, were read and approved.

No further business coming before the Section, the discussion of the evening on "Present Day Needs in Structural Materials," was opened with a paper by S. D. Foster, County Road Engineer, read by the Secretary, on "Road Materials."

Other papers were read as follows: C. B. Asher, of the National Fireproofing Company, on "Fireproofing Materials"; Kenneth Seaver, of the Harbison-Walker Refractories Company, on "Refractory Materials"; E. F. Wendt, of the Pittsburgh and Lake Erie R. R., on "Timber", and R. B. Woodworth, of the Carnegie Steel Company, on "Steel."

The ensuing discussion was participated in by Messrs. Woodworth, Hiles, Duff, Daum, Ferguson, Bleininger, Jones, Cronemeyer, Judd, Whitman, Seaver and Ashley.

The meeting adjourned at 10:40 P. M.

ELMER K. HILES, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, Friday, 4 March, 1910, at 4:45 P. M., President Morse presiding, Messrs. Lyons, Chester, Frost, Raymer, Whited, Covell and the Secretary being present.

The minutes of the last regular meeting, held 11 February;

and the minutes of the special meeting held 28 February, were read and approved.

Applications of the following gentlemen were received and their names ordered published to the Society:

Active

Harry Boyd Errett — Samuel L. Fuller
Stephen Lincoln Goodale — William Elton Mott
C. F. W. Rys.

Junior

F. Warren Kay — Harold O. Hill
Paul I. Keeler

The report of the Secretary, showing the financial condition of the Society at the close of business 28 February, 1910, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The question of advisibility of forming a special grade of Student Membership in the Society was discussed. The Secretary presented information touching on the corresponding grade of membership in the American Society of Mechanical Engineers. After favorable comment the matter was laid over for final consideration at the next meeting.

President Morse introduced the matter of appointing a disinterested committee to report on the question of elevating the bridges over the Allegheny River in Pittsburgh, in accordance with a request made by the Pittsburgh Chamber of Commerce.

After discussion it was recommended that President Morse appoint such a committee of five to report on the advisibility of raising these bridges.

The following members of the Society were appointed on this committee:

Julian Kennedy
James K. Lyons
John N. Chester
F. L. O. Wadsworth
Emil Gerber

No further business being presented the meeting adjourned at 6:05 P. M.

ELMER K. HILES, Secretary.

REGULAR MONTHLY MEETING

The 301st regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Fulton Building, Pittsburgh, Tuesday, 19 April, 1910, at 8:20 P. M., President Morse presiding, 50 members and visitors being present.

The minutes of the last meeting were read and approved.

The Board of Direction reported the election of seven Active members and three Juniors; the restoration of two gentlemen to Active Membership, and the receipt of five applications for Active membership, which were ordered published to the Society.

The ballot on the revision of By-Laws, ordered published to the Society 15 February, 1910, resulted in a unanimous vote for the revision as published.

The matter of Student membership was referred to the Membership Committee with request that the necessary changes in the By-Laws looking towards the establishment of a Student grade of membership in the Society for Juniors and Seniors pursuing a technical course in universities and technical schools be submitted to the Board at an early date.

The appointment of a committee consisting of Messrs. Geo. S. Davison, W. G. Wilkins and Emil Swensson, was announced, to examine into the questions in connection with the H. R. Bill to increase the Corps of Engineers in the United States Army, and to take up with our Senators and Representatives such features as involve the interests of civilian engineers.

The appointment of a committee consisting of President Morse, S. A. Taylor and A. R. Raymer was announced, to take up with our Representatives in Congress the provisions in the Sundry Civil Bill, relating to the investigations of structural materials, endeavoring to secure such modifications as will hold the Government Testing Station in Pittsburgh, and increase the appropriations for this work.

No further business coming before the meeting, the paper of the evening on "The Value of Geological Science to the Petroleum and Natural Gas Business," was presented by Fred-

erick G. Clapp. The ensuing discussion was participated in by Messrs. Geo. S. Davison, H. W. Fisher, R. B. Woodworth, W. H. Hall, F. B. Martin, P. S. Whitman and F. G. Clapp.

The meeting adjourned at 10:00 P. M.

ELMER K. HILES, Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Fulton Building, Tuesday, 5 April, 1910, at 8:20 P. M., Chairman Stucki presiding, 50 members and visitors being present.

The minutes of the last meeting held 1 February, 1910, were read and approved.

No further business coming before the Section, the paper of the evening on "The Selection of a Boiler Feed Water," was read by Mr. J. C. W. Greth, Manager of the Water Purifying Department of William B. Scaife & Sons.

The ensuing discussion was participated in by Messrs. B. A. Ludgate, Assistant Engineer of the P. & L. E. R. R.; C. D. Chamberlain; E. C. Trax; C. D. Young, Assistant Engineer Motive Power, Pennsylvania Lines; Jas. O. Handy; Richard Hirsch; E. K. Hiles and J. C. W. Greth.

The meeting adjourned at 10:25 P. M.

ELMER K. HILES, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Fulton Building, Pittsburgh, Friday, 8 April 1910, at 4:55 P. M., President Morse presiding, Messrs. Chester, Handy, Raymer, Riddle, Taylor, Whited, Covell and the Secretary being present.

The minutes of the last regular meeting, held 4 March, 1910, were read and approved.

The applications of the following gentlemen having been regularly published to the Society pursuant to the action of the Board on 11 February and 4 March, 1910, were duly elected to membership:

Active

Henry E. Cole,
Harry Boyd Errett,
Stephen Lincoln Goodale,
Samuel L. Fuller,
William Elton Mott,
C. F. W. Rys.
Per H. Schedin.

Junior

Harold O. Hill,
F. Warren Kay,
Paul I. Keeler.

Requests for reinstatement were received from the following gentlemen, and their names ordered placed on the Society rolls:

P. E. Hunter, who joined in Mar. 1896; resigned Feb. 1898.

J. A. Hunter, who joined in Mar. 1903; resigned Jan. 1905.

Applications of the following gentlemen were received and their names ordered published to the Society.

Active

A. R. Archer,
H. F. Banfield,
H. R. Blickle,
C. E. Mellsop,
Kenneth Seaver.

The report of the Secretary, showing the financial condition of the Society at close of business 31 March, 1910, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The Secretary reported that 111 votes had been cast for the revision of the By-Laws ordered published to the Society 15 February, 1910. All votes cast approving the changes in the By-Laws.

The matter of Student Membership was referred to the Membership Committee, with the request that the necessary changes in the By-Laws, looking to the establishment of a student grade of membership in the Society for Juniors and Seniors pursuing a technical course in universities and technical schools, be submitted to the Board at its next meeting.

President Morse introduced the matter of a bill before the House of Representatives to increase the corps of engineers of the United States Army, referring to an editorial in the current issue of the Engineering News on this subject. After discussion President Morse was authorized to appoint a committee of three to look into the matter in connection with this bill and to take up with such Senators and Representatives with whom we have influence, the questions involved as bearing upon the interest of civilian engineers. Messrs. Geo. S. Davison, W. G. Wilkins and Emil Swensson were appointed on the Committee to examine into this matter.

H. R. Bill Relating to Structural Materials Investigation: The Secretary reported that he had been advised that the item of the Sundry Civil Bill relating to the work on structural materials investigations at the government testing station in Pittsburgh, had been materially changed in the Appropriations Committee. After discussion President Morse was requested to appoint a committee of three members of the Board of Direction, consisting of himself, S. A. Taylor and A. R. Raymer, to interview the congressmen from the local districts, and endeavor to secure their active interest in having necessary changes made in the item above referred to.

The meeting adjourned at 5:45 P. M.

ELMER K. HILES, Secretary.

REGULAR MONTHLY MEETING

The 302nd regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Oliver Building, Pittsburgh, Tuesday, 17 May, 1910, at 8:10 P. M., President Morse presiding, 85 members and visitors being present.

The minutes of the last meeting held 19 April, were read and approved.

The Board of Direction reported the election of five Active members; the receipt of applications from 13 candidates for Active membership and one for Associate; and the restoration to membership of one applicant for reinstatement.

No further business coming before the Society, the paper of the evening on "Economical Methods of Construction in Reinforced Concrete," was presented by Robert A. Cummings.

The ensuing discussion was participated in by Messrs. W. G. Wilkins, Edward Godfrey, and R. A. Cummings.

The meeting adjourned at 10:45 P. M.

ELMER K. HILES, Secretary.

SPECIAL MEETING

A special meeting of the Engineers' Society of Western Pennsylvania was held Tuesday, 31 May, at 8:20 P. M., in accordance with a call to receive and consider a report of the five engineers appointed to investigate the question of raising the bridges over the Allegheny River in Pittsburgh, in conjunction with a Committee from the Chamber of Commerce.

The meeting was called to order at 8:20 P. C., President Morse presiding, 84 members and visitors being present.

President Morse made an address outlining the reasons for calling the meeting and requesting the Secretary to read a letter from Mr. J. N. Chester, addressed to Mr. Logan McKee, Secretary of the Chamber of Commerce; a letter from Mr. Emil Gerber to Mr. A. M. Hanauer, Chairman of the General Com-

mittee of the Chamber of Commerce on Bridge Raising, and also the second report to the Chamber of Commerce which was signed by Messrs. James K. Lyons, F. L. O. Wadsworth, J. N. Chester, Emil Gerber and Julian Kennedy, the five engineers appointed by the President to consider the matter of bridge raising.

Mr. I. W. Frank, a member of the General Committee on Bridge Raising of the Chamber of Commerce, addressed the meeting, outlining the action of this Committee and its sub-committees.

Mr. J. K. Lyons, one of the five engineers from the Engineers' Society of Western Pennsylvania, who were members of the above mentioned General Committee, replied to Mr. Frank, taking exceptions to the statement that the report presented to the Chamber of Commerce had been properly adopted by the General Committee.

Messrs. Morris Knowles and W. G. Wilkins called for the Secretary to proceed with reading the letters and report.

Mr. Alexander Dempster wanted information as to how this matter came to be before the Engineers' Society of Western Pennsylvania for consideration as he considered it a matter solely before the Chamber of Commerce.

President Morse explained that the five engineers appointed from this Society to act in conjunction with a Committee from the Chamber of Commerce, desired to report their views on the matter of Bridge Raising to the Engineers' Society of Western Pennsylvania. He then requested the Secretary to proceed with the reading of the letters and report above referred to.

The Secretary read the following letter from Mr. J. N. Chester:

"Mr. Logan McKee, Secretary,
Chamber of Commerce, City.

Dear Sir:

I have just received your notice of May 19th, calling the entire Committee on Bridge Raising to meet Friday, May 20th at 1:30, and as I shall be out of the City I submit the following:

You know that I voted only once in the Sub-Committee yester-

day and the "Aye" on the necessity of facilities for navigation of the Allegheny River being provided.

As regards the stern wheel type recommendation the fact that this is the only type used by the river men is not to me at all convincing and so, being in doubt, I did not vote at all.

In regard to the 28 ft. high boat recommendation, I did not vote because I believe all the navigation that will develop within the next decade on the Allegheny River can be economically cared for by any of the 24 to 25 ft. boats now used on the Monongahela.

As to stage, height and the bridge raising question in general, I would vote against anything having a grade of over 3½ percent for approaches or grades on bridge of over 2 percent.

I should like my vote recorded on all questions raised in accord with the above. Yours very truly,

(Signed) J. N. Chester."

"I after wired from Chicago that I believed that within the next decade lower boats would be designed and adopted for all such river traffic, and thereby be able to take care of the traffic on the river for many decades to come without interference."

The Secretary next read the following letter from Mr. Emil Gerber:

"Mr. A. M. Hanauer, Chairman,
General Committee on Bridge Raising,
Chamber of Commerce, Pittsburgh, Pa.

Dear Sir:

As I will be unable to be present at the meeting of the Committee and take part in the deliberations, I take this opportunity of expressing my views on the matter before the committee. As I understand it, the proposition which we are to investigate is, "Shall the bridges over the Allegheny River, within the city limits of Pittsburgh, be raised to 47 feet above low water or not?"

As I understand it, the height of the bridges is no material obstruction to the commerce which now passes under them, as that commerce is very limited in extent and has been on the decline. The object of raising bridges is to make it possible for larger boats of the present type to pass under them, so that a greater commerce may be developed; such prospective increase in commerce being largely coal from the Freeport district. The locks in the existing dams in the Allegheny are comparatively small, and not more than four barges can be taken through at once, which can be handled by the existing boats in all ordinary water stages, although at high water there might be some difficulty. More powerful boats would, therefore, be of value at high water stages.

Mr. Bettinger in addressing the committee the other day, quoted from the language of a poet to the effect that "Prophecies are written in poetry and history in prose," applying it to the boat "Rumsey." I was struck at the time with the aptitude of his quotation to the whole subject of future commerce on the Allegheny. The history of the improvement of the navigable rivers of the United States was well set forth by Mr. Gordon the other day, when he said that notwithstanding all the money spent on the improvement of the various rivers of the country, there are none, except the Monongahela, in which the business has not decreased at least 50 percent. It is questionable, therefore, whether any improvement of the Allegheny River whatsoever will make a commerce which does not now exist or divert any of that which the railroads are handling so ably. In the early days when the country was being settled, the rivers were used as highways because they were the most convenient routes, but since a railroad was built, paralleling the river, the convenience of doing business by the railroad was so much greater than by steamboat that the railroad took the commerce. It is not reasonable, therefore, that a line of boats established on the Allegheny would take away any commerce from the railroads.

And there is, therefore, no reasonable hope of developing a waterborne commerce on the Allegheny River. I do not see why the people of Pittsburgh should spend money to improve the river. I know of no commercial enterprise in which the management would spend money to take care of a future contingency which is improbable on the face of it, and even, if possible, would be some years in developing. It is my firm belief, therefore, that there is at present no occasion for raising bridges over the Allegheny river.

I do think that the steamboat people have some reason to complain, on account of the location of the piers of some of the bridges. The bridges within the city limits of the City of Pittsburgh are over a harbor rather than over a channel and should, therefore, be treated differently from a bridge located some miles beyond the city, where boats merely pass and do not habitually land. In a harbor the shores should be unobstructed; in a navigable channel, it is usually preferable to have the middle of the stream unobstructed. A bridge with piers like that at Sixth Street is better adapted for harbors than one which has a long span in the middle and two piers in the water rather close to shore. It is my opinion, that all of the bridges within the city limits of Pittsburgh over the Allegheny River should ultimately be made to conform to the general plan of the Sixth Street Bridge; viz., to have one middle pier and two abutments located high enough on the bank to be entirely out of the way at any navigable stage. I do not believe that the matter is of sufficient importance that the bridges

which do not conform to this requirement should be immediately changed, but I do think that a regulation should be made requiring that whenever any of the bridges, which now have four spans with three piers in the water, are materially altered or rebuilt, that the piers near shore should be removed and the water-way spanned by two spans with one pier in the middle of the river, and two abutments so far on shore as to be back of navigable water, and that such reconstruction should take place within ten years from date. The height of such bridges when rebuilt should not be less than the Sixth Street bridge.

I have not mentioned the relative merits of traffic over and traffic under the bridges, nor different types of boats. It is said that we have a 7 percent grade on the hump, and there is no reason why we should not have it on the bridges. This argument might be turned around to read that we are spending money to reduce the grade on the hump and it would look ridiculous to spend more money to get steeper grades across our bridges. If the grade is objectionable on the hump, it would certainly be objectionable on the bridges because more traffic passes over the bridges than goes over the hump and the tonnage going over the bridges is so much greater than that going under them that if the greatest good to the greatest number is considered, we should certainly not increase the height and grade of our bridges.

Furthermore, I believe something can be accomplished in the way of reducing the height of boats even if the present type is retained. The boilers can be lowered two or three feet if the hull is properly built, and, no doubt, other changes can be made if necessary, so that a more powerful boat can be built that will not be higher than the present boats that work under the bridges.

We may, moreover, expect to see an entirely new boat devised that does not require so much height, I do not look for it in a screw propeller, unless it is in a double ender.

Heretofore, whenever it was desired to improve the navigable rivers of the country, it has been by general taxation and private interests that interfered with the plans have had to suffer. Is it not about time that the steamboat owners contributed something toward improving their own conveniences?

The question of the Allegheny River navigation is only one of several which will have to be taken into consideration before making any changes in the bridges. We have a sewerage problem and a flood regulation problem, and when these are worked out it may be found desirable to make alterations in the bridges, and all of these things should be taken into consideration before any changes are ordered in the bridges, whether the bridges are owned by the city, by corporate, or by private interests.

For the reasons set forth, I am opposed to any changes in the bridges at the present time, and only in favor of such changes as already above outlined for the next ten years, or until such time as sewer and flood protection matters are fully decided.

Very truly yours,

(Signed) E. Gerber."

The Secretary then read the following report made by the five engineers appointed from this Society and sent to the Chamber of Commerce:

"In a report presented to the Pittsburgh Chamber of Commerce on May 23rd, 1910, the Special Committee on Bridge Raising has gone on record as having reached certain conclusions which are embodied in the three following resolutions:

"Resolved, First, that the Committee recommend to the Chamber of Commerce that it recommend to the United States Government that the bridges crossing the Allegheny River be so elevated as to permit a craft that will stand not over twenty-eight (28) feet above the water level to navigate when the river stage is sixteen (16) feet, with a reasonable clearance not to exceed two (2) feet, which will call for the raising of the bridges to an elevation of forty (40) feet above the pool level understood to be six (6) feet, and

Resolved, Second, that for the purpose of obtaining minimum grades on the bridges, that the plan of center pier construction be maintained so long as it does not interfere with the alignment of the pier of the channel way, as per the tentative plan hereto attached, and

BE IT FURTHER RESOLVED, that the committee deems that the present and available traffic on the Allegheny River is of sufficient magnitude and importance to warrant the Chamber of Commerce in recommending to the United States Government that it continue to improve the said stream to the end that the navigation thereon may be free and practically unobstructed.'

It is further stated in the report that the above resolutions "were adopted unanimously by the Committee."

The statement just quoted is not correct and it is an injustice to a number of members of the Special Committee. The circumstances under which the report of May 23rd was presented, are briefly stated as follows:

A meeting of the entire Committee was called by Chairman Hanauer on May 20th, to consider the reports of the two (2) sub-

committees previously appointed, and to consider further the questions which will be raised by the necessarily conflicting reports of these two (2) subcommittees. There was no member of the Committee appointed by the Engineers' Society present at this meeting, and the only report presented on the matter of grades was a short verbal one by Mr. George, the chairman of the subcommittee on that subject. The subcommittee on type of river craft presented a short two (2) page report which was signed by six (6) members of the subcommittee, but was not signed by one of the Engineers on the Committee, the Engineer in question, Mr. J. N. Chester, having presented a minority report which was not submitted to the general committee. At this meeting certain resolutions embodying the subject matter of these contained in the final report were presented for consideration, and it was voted that a copy of such proposed resolutions should be sent to each member of the Committee for his individual consideration. This was not done. At a second meeting called May 23rd, the proposed resolutions were considered but were not adopted by a majority of the committee present and were presented to the Chamber of Commrce without being approved. One member at least of the Committee wrote a letter to Chairman Hanauer, setting forth very clearly his views in opposition to the raising of the bridges. In view of all these facts, it will be seen that the statement as to the unanimous adoption by the Committee of the resolutions presented to the Chamber of Commerce as embodying the conclusions reached by that Committee is not warranted and is extremely unfair to those whose views differ from the views expressed in the resolutions presented. For this reason certain members of the Committee have felt it incumbent upon themselves to present a second report setting forth very briefly the points on which they differ from those members of the Committee who have signed the report already presented.

The determination of the question as to whether or not the present bridges over the Allegheny River shall be raised rests simply on a comparison between the possible advantages to be obtained by such raising and the actual advantages secured by maintaining the bridges at their present level. In order to compare these relative advantages the following matters must be carefully considered:

FIRST: The question of how the elevation of the bridges to the height desired by the River interests, or to any height, will affect the grades on both the bridges themselves and on the street approaches thereto, and the question of how these changes in grade will affect the traffic over the bridges. There can be no possible question but what the most desirable condition so far as the traffic over the bridges is concerned is a level roadway without any grade at all. Such a condition, however, is not a possible one even under pres-

ent conditions. The important question before the Committee is what grade can be allowed without serious inconvenience to the traffic and without introducing elements of danger. Certain very definite data on this matter is obtainable from the results of long experience with bridges in general, and with the Smithfield Street bridge over the Monongahela River in particular. In modern bridge construction the necessity for reducing dead load to as small a figure as possible renders imperative the use of planking or wooden blocks as paving for the bridge roadway. With such a form of road bed it is hardly possible to use a grade of over 2½ percent without imposing serious restrictions on the traffic on such road bed, particularly in wet and slippery weather. The maximum grade on the Smithfield Street bridge roadway is 2.56 percent, and even with this grade horses drawing very heavy loads will frequently slip and fall when the road bed is wet or is covered with ice or snow. The traffic over the Allegheny River bridges is so heavy, and the development of the city industries depends so absolutely on its unrestricted development that only the most important and weighty considerations should be allowed to interpose any obstacles or difficulties in the way of such traffic. Certain of the present bridges over the Allegheny River have grades which exceed the grade above mentioned, but the effect should be to reduce these grades rather than to increase them, particularly in view of the fact that the traffic over the bridges is constantly increasing and the importance of maintaining free and unrestricted communication between the different sections of the city is of greater and greater importance from now on. Intimately connected with this question of easy and unobstructed communication between the different city sections is the question of cost of transportation between these sections.

SECOND: As a second question, therefore, we have to consider how the elevation of the present bridges will affect the cost of hauling from the North Side to the Point districts of the city. It is an indisputable fact that any elevation whatsoever will increase the cost of transportation over the bridges, since quite independently of the question of grade, an elevation of height necessarily means an elevation of the loads to the height represented by the maximum raising of the bridge floor. Just what this increased cost will amount to is not easily determinable, but the estimate given in Mr. Sprague's report to the Mayor of Pittsburgh, and submitted by him to the Secretary of War, is in our opinion, based upon carefully considered and reasonably accurate data and is fair and conservative. As based on the changes of grade proposed by the United States Board of Engineers, the estimated additional cost of hauling over the bridges would be between $300,000 and $400,000 per year. This leaves entirely out of account all of the freight handled over the railroad bridges, all of the

street car transportation, and all of the traffic represented by pedestrians, pleasure vehicles and light wagons.

THIRD: The question of how the elevation of the present bridges will affect the grades of the present down town streets of Pittsburgh and the North Side. If it is desired to avoid grades above 2½ percent on the bridge road ways by raising the street levels at the bridge approaches, such raising of the street levels will involve not only a very great expense in the change of elevation in the street itself, but will involve questions of damage to adjacent property that may easily run into millions of dollars. Indeed questions of this nature are so far reaching in their character as to make their consideration at the present time almost impossible. On the Point Side of the River the questions now under consideration are further complicated by the fact that any raising of the present street levels would necessarily involve the raising of the tracks of the Pennsylvania Railroad on Duquesne Way, a change which would involve a very large additional expense, even if the railroad could be forced to make it at all.

FOURTH: The question of how the present elevation of the bridges would be affected by the adoption of any plans presented by the Flood Commission. The matter of eliminating or reducing the annual damage by floods in the Allegheny River is one of such tremendous importance that any final decisions as to the matters under consideration by this committee should not be reached without giving a great deal of thought to this matter in its relation to the questions before the Committee. Such consideration cannot be given until the Flood Commission has made its final report.

FIFTH: The question as to the probable and prospective increase in traffic on the Allegheny River, as affected by the question of clearance under the bridges at different stages of water. It is admitted that the increase which might result to this traffic from an elevation of the bridges is at this stage of the inquiry purely spectulative. But it is also admitted that such increase is likely to occur, and that the plans of the United States Government for improving the Allegheny River should be carried out. These plans, however, are not in themselves dependent upon an elevation of the bridges above the present levels save in the case of the Thirtieth Street and Forty-third Street bridges, where the conditions make it desirable that the structure should be elevated to eliminate grade crossings quite independently of the question of elevation for river traffic. That is to say, it does not appear at all certain but that such a type of river craft can be easily developed as will render river navigation at all stages of water where such navigation is desirable at all, thoroughly possible and practicable. With the exception of the two (2) bridges above mentioned, all of the present Allegheny River bridges in

Pittsburgh have an elevation of nearly thirty-five (35) feet above pool level, and this makes it possible to navigate under these bridges on a twelve (12) foot stage of water six (6) feet above pool level, even if boats twenty-eight (28) feet in height are found necessary. The twelve (12) foot stage is considered to be the ordinary limit of navigation in the Allegheny River on account of the swift current which is there found and an examination of the river records over a period of more than fifty (50) years, (from 1866 to 1907), shows that on the average there are only twenty-seven (27) days in the year when the river reaches a twelve (12) foot stage. The number of days when the river is above a twelve (12) foot stage, and when therefore the present bridges (except the Forty-third Street Bridge) would offer obstruction to boats twenty-eight (28) feet in height is, of course, still less.

SIXTH: The question of whether efficient types of river craft cannot be built with a height of considerably less than twenty-eight (28) feet. This question is not affected in any way by the question of the type of propulsion for the boats. The height of the wheels in the present type of stern wheel river boats is from sixteen (16) to eighteen (18) feet; as far as that particular form of propulsion is concerned, the wheel itself is, therefore, much less in height than the other portions of the boat. There do not seem to be any convincing facts presented to the Committee which show the necessity for a height of twenty-eight (28) feet, and until such facts are presented it does not seem logical to make the determination of such an important question as is before this Committee, rest upon the acceptance of an existing type and construction of river craft as the only possible type and construction that can be used. Experience in other parts of the world has demonstrated conclusively the possibility of building boats much lower than this, and such possibilities ought at least to be thoroughly exhausted before compelling the Pittsburgh public to expend millions of dollars, as they would be compelled to do if the bridges were elevated to any great height above their present levels. This is particularly true in view of the fact that this year's River and Harbor Bill carries with it a large appropriation for conducting an investigation and a series of experiments for the purpose of determining the best type of construction of boats for use on non-tidal rivers.

SEVENTH: The question of possible obstruction to navigation, due to the present location of bridge piers in the Allegheny River. This is a question which should, in our opinion receive immediate consideration. The present location of the piers of some of the bridges is undoubtedly bad. Some systematic and uniform plan of locating the piers of the different bridges so as to leave straight and open channels down the river should be at once adopted and consistently adhered to, both in repairing the present bridges, when repairs are necessary,

and in building new ones. The location of a line of piers in the center of the river would be consistent and uniform with the arrangement adopted in the new Point Bridge and in the present Sixth Street, Seventh Street and Fort Wayne Railroad bridges, and would, everything considered, seem to offer perhaps the greatest advantages.

SUMMARY

To sum up briefly, our conclusions are that no one individual set of interests, the River interests, the Railroad interests, the Street Car interests, or any other private or corporate interests, shall be considered in comparison with the interests of the public as a whole. These public interests are so large and so varied, and to a great extent so indeterminate, (as regards possible development of traffic on the Allegheny River), that it seems almost impossible to reach any final and ultimate conclusions as to how these interests can be best served without much fuller consideration of all the questions above briefly outlined, than has been possible up to the present time, or will be possible for some time to come. So far as any conclusion can be reached at this time, the facts now before the Committee clearly show that the greatly preponderating evidence favors a retension of the bridges (except the Thirtieth and Forty-third Street bridges, see supra.) at their existing levels for the present; with a re-location of the bridge piers where necessary, so as to give continuous and uninterrupted channels on each side of the river and ready access to the wharves on both sides.

(SIGNED)

James K. Lyons,
F. L. O. Wadsworth,
J. N. Chester,
Emil Gerber,
Julian Kennedy.

Mr. Knowles presented some resolutions which he requested the Secretary to read.

Mr. Alexander Dempster raised a point of order that the report of the five engineers was not properly before the Society as he considered it a matter only for the consideration of the Chamber of Commerce.

President Morse ruled that the report was properly before the meeting and requested the Secretary to read the resolutions offered by Mr. Knowles, which were read as follows:

WHEREAS, the Engineers' Society of Western Pennsylvania, in response to a request from the Pittsburgh Chamber of Commerce, ap-

pointed through the President and Board of Direction of the Society, five disinterested Engineers; to act with the Committee from the Chamber of Commerce, to report upon the subject of Bridge Raising, and,

WHEREAS, the said engineer members acted with the whole Committee, but their views and vote were not recorded nor presented to the Chamber, and,

WHEREAS, the report presented to the Chamber of Commerce by said "Bridge Raising Committee," called for the raising of the bridges to a height of 40 feet, and was therein stated to be the unanimous action of the Committee and thus adopted by the Chamber, and,

WHEREAS, the five engineer members of the Committee, together with two other members of the main committee, making seven in all, have prepared a second report to the Chamber of Commerce and copy of which report, signed unanimously by all the engineer members of the Committee, has been submitted to the Engineers' Society of Western Pennsylvania, as a statement of the investigations and finding of the Engineer members of the above named Committee, for the information of the Engineers' Society, and,

WHEREAS, in view of the paramount importance of the varied interests of the whole public in the bridge question and the many other conflicting interests and statements of the requirements of services to be accomodated and also, in view of,

First—The present investigations by the Flood Commission composed in part of members of this Society; as to the conditions, causes and possible remedies from flood disasters;

Second—The purposes of the City of Pittsburgh, under the guidance of a member of this Society, to elevate some streets and low lands and possible improvements of wharfs, approaches and sewerage system;

Third—The suggested rearrangement of the traction service and the probability of combining bridge raising with the elimination of certain railroad grade crossings;

Fourth—The necessity of a rearrangement of some bridge piers and improvement of the river channel;

Fifth—The study of best type of river craft for such river and thus the required clearance height for bridges; because all will be studied by engineers and all of these factors will effect at least two or three or more of the various bridges; and make for the desirability of postponing definite action until most or all of these problems are determined, which can and should be done within a year.

THEREFORE BE IT RESOLVED, that a copy of this "Second Report," as endorsed by the engineer members of the Committee of the Chamber of Commerce, be received and filed and that the said five engineers be constituted a Committee of the Engineers' Society of Western Pennsylvania, upon "Bridge Raising," to continue the investigation and report.

BE IT FURTHER RESOLVED by the Engineers' Society of Western Pennsylvania, in a meeting assembled May 31st, 1910, that it is the opinion that no action should be taken by the Secretary of War at this time, that would operate as a final decision in the matter of raising the bridges over the Allegheny River at Pittsburgh and that such final action be deferred until the many matters of public policy inter-relating to such a problem, and hereinbefore recited, be settled and determined, and,

BE IT FURTHER RESOLVED, that the President and Secretary of the Engineers' Society be requested to send a copy of these resolutions together with a copy of the above mentioned "Second Report," as unanimously endorsed by the Engineers' members of the Committee, to the Honorable Secretary of War.

The adoption of these resolutions was moved by Mr. Morris Knowles and seconded by Mr. W. G. Wilkins.

Considerable discussion ensued at this point which discussion was participated in by Messrs. I. W. Frank, W. G. Wilkins, Alexander Dempster, J. K. Lyons, F. L. O. Wadsworth, T. M Rees, T. P. Roberts, T. H. Johnson, and C. D. Marshall.

Mr. I. W. Frank moved that the resolutions be laid on the table, which motion was seconded.

The motion to lay on the table was put to vote and lost by a large majority.

The question before the meeting being called for, the motion to adopt the resolutions offered by Mr. Knowles was put to vote and carried by a large majority.

The meeting adjourned at 10:30 P. M.

ELMER K. HILES, Secretary.

[At the meeting of the Society held March 15, 1910, President Morse was authorized to appoint the above named members of the Society as a Committee to report on the question of the advisibility of raising the bridges over the Allegheny River. See minutes of this meeting published in the April, 1910, issue of the Proceedings.]

STRUCTURAL SECTION

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Oliver Building, Pittsburgh, Tuesday, 10 May, 1910, at 8:15 P. M., Chairman V. R. Covell presiding, 30 members and visitors being present.

The minutes of the last meeting held 1 March, 1910, were read and approved.

No further business coming before the Section, the discussion of the evening on "Lumber" was opened by Mr. F. R. Babcock, of E. V. Babcock & Company.

The ensuing discussion was participated in by Messrs. T. H. Johnson, T. D. Lynch, Willis Whited, and others.

The meeting adjourned at 10:35 P. M.

ELMER K. HILES, Secretary.

BOARD OF DIRECTION

A special meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Oliver Building, Pittsburgh, Wednesday, 11 May, 1910, at 12:30 P. M., President Morse presiding, Messrs. Craver, Handy, Raymer, Taylor, Lyons, Whited and the Secretary being present.

The applications of the following gentlemen were received and their names ordered published to the Society:

Active,

Alfred R. Allard,
Clayton G. Bunnell,
George T. Haldeman,
William M. Kinney,
Claire G. Landes,
Robert A. McKean,
Henry S. Ow,
William I. Parry,
Charles M. Reppert,
Otto C. Reymann,
Jos. L. Risacher,
Harry B. Rust,

Associate,

John W. Macartney.

In view of the opposition which developed at Washington, with reference to the Government Testing Station in Pittsburgh, the Secretary was authorized to send a circular letter to all

members of the Society, requesting them to write to Pennsylvania Congressmen as well as others urging that the testing of structural materials be retained in charge of the Bureau of Mines, and not transferred to the Bureau of Standards, and that the appropriation be increased to $150,000.00.

President Morse introduced the matter of the opposition which had developed at Washington to the appointment of Dr. Joseph A. Holmes as Director of the newly formed Bureau of Mines. After discussion the President and Secretary were authorized to send a letter to President Taft urging the appointment of Dr. Holmes as Director of the Bureau of Mines.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Oliver Building, Friday, 13 May, 1910, at 5:15 P. M.; President Morse presiding, Messrs. Riddle, Grace, Craver, Handy and the Secretary being present.

The minutes of the last regular meeting held 8 April; and minutes of the special meeting held 11 May, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society, pursuant to the action of the Board on 8 April, were duly elected to membership:

Active,

A. R. Archer, H. R. Blickle,
H. F. Banfield, C. E. Mellsop,
Kenneth, Seaver,

A request for reinstatement was received by F. E. Field, who joined the Society December 20, 1904, and resigned February 8, 1908. His name was ordered placed on the Society rolls.

The report of the Secretary showing the financial condition of the Society at close of business 30 April, 1910, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The Secretary advised the Board that the Society at its last meeting referred the matter of impending legislation on the Metric System, for consideration. The matter was ordered laid on the table.

The meeting adjourned at 6:15 P. M.

ELMER K. HILES, Secretary.

REGULAR MONTHLY MEETING.

The 303rd regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the society rooms, Oliver Building, Pittsburgh, Tuesday, 21 June, 1910, at 8:15 P. M., President Morse presiding, 135 members and visitors being present.

The minutes of the regular meeting held 17 May and the special meeting held 31 May, 1910, were read and approved.

The Board of Direction reported the election of thirteen Active Members and one Associate; the restoration to membership of one applicant for reinstatement; the receipt of thirteen applications for Active Membership and six for Junior Membership.

Certain amendments to Section 3 of Article IV of the By Laws were recommended by the Board of Direction to the Society. This By Law with suggested amendments reading as follows:

ARTICLE IV.

SECTION 3. The *annual dues* shall be payable on January 1st, in advance. Resident Active Members and Resident Associates shall pay $10.00 per annum; Juniors shall pay $5.00 per annum, except as hereinafter provided, for not more than seven years, after which period their dues shall be the same as Active Members. Juniors, who are students in schools of recognized standing, shall pay $3.00 per annum. Non-Resident Active Members and Non-Resident Associates shall pay $5.00 per annum.

The Secretary announced the death of the following members of the Society:

Walter C. Kerr, who joined the Society in September, 1902, died 8 May, 1910, at Rochester, Minn.

J. A. Thorsell, who joined the Society in April, 1899, died 6 May, 1910.

No further business coming before the Society the paper of the evening on "Low Pressure Steam Turbines," by F. E. McKee, was read, in the author's absence, by R. F. Patterson.

The ensuing discussion was participated in by Messrs. F. G. Gasche, Mechanical Engineer of the Illinois Steel Company,

Chicago; E. D. Dreyfus, Engineer with the Westinghouse Machine Company, Pittsburgh; L. E. Phillips, of the Allis-Chalmers Company; Francis Hodgkinson and W. B. Flanders, of the Westinghouse Machine Company; Prof. C. L. W. Trinks and H. F. Affelder.

The meeting adjourned at 10:30 P. M.

ELMER K. HILES, Secretary.

MECHANICAL SECTION.

The regular bi-monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 7 June, 1910, at 8:20 P. M., Chairman Stucki presiding, 40 members and visitors being present.

The minutes of the last meeting held 5 April, 1910, were read and approved.

No further business coming before the Section, the paper of the evening on, "Air Conditioning Apparatus," was read by W. H. Carrier, Chief Engineer of the Carrier Air Conditioning Company of New York.

The ensuing discussion was participated in by Messrs. A. R. Raymer, B. A. Ludgate, E. K. Hiles, F. C. Schatz, V. R. Covell, John Allison and W. H. Carrier.

The meeting adjourned at 10:20 P. M.

ELMER K. HILES, Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Oliver Building, Monday, 13 June, 1910, at 5:00 P. M., President E. K. Morse presiding, Messrs. Handy, Craver, Taylor, Chester, Raymer, Whited, Covell and the Secretary being present.

The minutes of the last regular meeting, held 13 May, 1910, were read and approved.

The applications of the following gentlemen having been

regularly published to the Society, pursuant to the action of the Board on 11 May, 1910, were duly elected to membership:

ACTIVE

Allard, Alfred R.	Bunnell, Clayton G.
Haldeman, Geo. T.	Kinney, William M.
Landes, Claire G.	McLean, Robert A.
Ow, Henry S.	Parry, William I.
Reppert, Charles M.	Reymann, Otto C.
Risacher, Jos. L.	Rust, Harry B.

Lehman, G. M.

ASSOCIATE

Macartney, John W.

A request for reinstatement was received from F. W. Salisbury, who joined the Society in January, 1904, and his name was ordered placed on the Society rolls.

Applications were received from the following gentlemen, and their names ordered published to the Society:

ACTIVE

Craig, G. B.	Frohrieb, L. C.
Hice, Richard R.	Irvin, C. R.
Kimball, Ralph E.	Manning, Harry G.
Power, Walter J.	Skinkle, Wm. B.
Price, C. S.	Straub, T. A.
Warner, Arthur O.	Wood, Geo. R.

Gerber, L. C.

JUNIOR

Abbe, Walter, Jr.	Anderson, Martin J.
Bell, Gilbert A.	Cochran, J. S.
Kline, Robert S.	Obermeyer, W. S.

The report of the Secretary, showing the financial condition of the Society at close of business 31st May, 1910, having been previously audited by the Finance Committee, was approved and bills ordered **paid.**

The Secretary read the recommendations made by the Membership Committee to whom the matter of changes in By

Laws necessary for a Student Grade of Membership was referred.

After discussion it was ordered that Section 3 of Article IV, amended as follows, be submitted to the Society at its next meeting:

ARTICLE IV.

SECTION 3. The *annual dues* shall be payable on January 1st, in advance. Resident Active Members and Resident Associates shall pay $10.00 per annum; Juniors shall pay $5.00 per annum, except as hereinafter provided, for not more than seven years, after which period their dues shall be the same as Active Members. Juniors, who are students in schools of recognized standing, shall pay $3.00 per annum. Non-Resident Active Members and Non-Resident Associates shall pay $5.00 per annum.

The Secretary announced the death of the following members of the Society:

Walter C. Kerr, joined Society September, 1902; died 8 May, 1910.

J. A. Thorsell, joined Society April, 1899; died 6 May, 1910.

The Secretary presented a report from Mr. Thomas H. Johnson, who represented the Society in a delegation to Washington which met President Taft and Secretary Ballinger, for the purpose of endorsing Dr. Jos. A. Holmes for the position of Director of the newly authorized Bureau of Mines.

The report was ordered filed.

The meeting adjourned at 6:20.

ELMER K. HILES, Secretary.

REGULAR MONTHLY MEETING

The 304th regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 20 September, 1910, at 8:15 P. M., President Morse presiding, 89 members and visitors being present.

The minutes of the regular meeting held 21 June, were read and approved.

Announcement was made of the appointment, by President Morse, of the Nominating Committee for 1910, as follows:

E. B. Taylor, Chairman,

Chester B. Albree, Morris Knowles,
J. K. Lyons, D. W. McNaugher.

Samuel E. Duff, Chairman of the Membership Committee, made a verbal report of the activities of this Committee, drawing attention to the fact that the number of applications for membership in the Society were increasing and that these applications were from engineers who would add largely to the strength and success of the Society. He suggested several ways that the individual members of the Society could materially assist the Membership Committee in their work, and requested that members advise the Committee of the names of men whom they considered would be valuable additions to our membership, in order that the Committee might extend an invitation to join the Society.

The Board of Direction reported the election of 13 Active members, and six Juniors; and the receipt of thirteen applications for Active membership, one for Associate, and four for Junior membership.

The receipt of the following letter and report of delegates to the National Conservation Congress was announced.

MR. E. K. MORSE,
President, Engineers Society of Western Penna.,
Pittsburgh, Pennsylvania.

Dear Sir:

I take pleasure in handing you herewith, the joint report of Mr. A. M. Gow and myself, whom you were pleased to appoint to represent the Engineers Society of Western Pennsylvania at the National

Conservation Congress held at St. Paul, Minn., Sept. 5th to 9th inclusive.

Mr. Gow has requested me, in presenting this report, to express to you and to the Society his high appreciation of the fact that, though far removed from active participation in the work of the Society, he has been thus remembered, and to assure you of the pleasure afforded him thereby.

I join with him in thanking you for the honor of representing our Society in that gathering of representative people from all parts of the country.

Most sincerely yours,
(Signed), THOS. H. JOHNSON.

To The President and Board of Directors of the Engineers Society of Western Pennsylvania.

Gentlemen:

Your delegates to the National Conservation Congress, held at St. Paul, Minn., September 5th to 9th inclusive, desire to report as follows:

We went to the Congress expecting to find a gathering of men who met together to consider the natural physical resources of the Country, their dissipation by wasteful and extravagant methods of operation, and to discuss, in a business-like manner, the ways and means of preventing waste and wanton destruction of what remains.

The natural resources which we had in mind were those which form the basis of our prosperity, and have figured so prominently in the discussions of the subject, during the past few years, in our legislative halls, in official reports, and in the public press; viz., our forests, coal and gas, minerals, water-supply and water power; together with the utilization of the public domain to a larger degree, by irrigation in the arid districts, and drainage of swamp lands.

But we found that a broader scope had been given to the objects and purposes of the Congress, by making it to include both *vital* and *natural* resources, and in the various addresses references were made to conservation of *fishes,* of *birds,* of the *patriotic spirit,* and of *true womanhood,* of *child life,* of *public health,* and other subjects; all interesting and profitable for discussion, but calling to the Congress too large a membership with too wide a field for effective work.

The total number of delegates registered was about 1400. No attempt was made to have the various topics investigated by Committees, who should collect and collate facts, digest data, and report recommendations for action. Neither was opportunity provided for general discussion of any one of the subjects supposed to be before the Congress.

On the contrary, the Executive Committee had prearranged a program of set speeches, (copy attached hereto) which filled the en-

tire five days session, and these speeches, with two or three notable exceptions, were not replete with information, nor wise suggestion of ways and means to a desired end; but were for the most part composed of oratorical periods, filled with generalities, and platitudes, interspersed with invective against "corporate greed," "predatory wealth" and "special interests." It seemed as though the chief aim was to arouse a sentiment in favor of Conservation in general, irrespective of definite data.

The address of President Taft was the most notable exception to the foregoing comment. He gave us definite statistics as to the area of the Public Domain still owned by the Government, its distribution in the different States, how much is forest, and how much agricultural land, how much has been withdrawn from sale as forest reserve, and similar statistics as to coal and gas lands. He cited the several acts of Congress touching these and other matters relating to the Public Domain, stated the powers and duties conferred on the Executive by them, and what had been done in accordance therewith, both by the Forest and Reclamation branches of the service. He suggested certain modifications of existing laws, to make the administration of the Public Domain more effective. He advocated the retention of ownership by the Government, which should provide for productive development under leaseholds for a limited time (say 50 years) and on reasonable terms, which would encourage rather than discourage development, and at the same time produce revenue.

A radical difference of opinion developed at the conference of the Governors of the States, on Tuesday afternoon, on the subject of National or State control of the national resources; and some bitter feeling was aroused. So far as the general feeling of the Congress on this subject was reflected in the speeches on the program, it might be summed up in the words of Gifford Pinchot, who advocated "National control of all resources now owned by the Nation; State control where ownership is in the State; and State regulation of private ownerships within the State jurisdiction, with State aid to private owners of forest lands in the matter of police and fire protection."

The proceedings, with all the addresses in full will be printed, and a copy will be furnished for the library of this Society.

The newness of the Conservation movement probably accounts for its lack of definiteness. Throughout the entire Congress there was an absence of definite idea as to what should be done, although Mr. Pinchot claimed to know just what he wanted and how to get at it. It is very probable that the majority of delegates had never given the subject any more serious consideration than had your two representatives.

We feel that the Conservation of our natural resources should be removed from the realm of "hot air" and flamboyant oratory and

brought where it belongs, into the field of engineering and business methods. If between now and the next meeting of the Congress the Engineering Societies of the country could get together and through wise counsel and cooperation lead to the creation of an Engineering Section of the Congress of 1911, they could make it an occasion for the presentation of the Conservation idea along Engineering lines, to the furtherance of the idea and the advancement of the profession. For while the promoter and the politician are necessary factors in the work, it is upon the Engineer, after all has been said and done, that the solution of the problems and the shaping of them into concrete form devolves. The problems are many and cover every branch of Engineering.

Just how the engineering phase of the conservation idea could be presented to the best advantage, we are not now prepared to state. This is a matter for study, consideration and consultation; but we beg to suggest that the Engineers' Society of Western Pennsylvania should take the initative in a movement with a view to the presentation of the Engineers' side of the question, at the next Congress. At that Congress there should be presented a series of papers by Engineers, which papers shall be notable in that they shall record and recount the "state of the art" in the year 1911 and be valuable for reference as authoritative documents. Just how to get these papers prepared is a matter for this Society to formulate, if it should approve of the suggestion and desire to set the ball rolling.

To illustrate: Let there be a paper upon the Fixation of Nitrogen. Let this paper present the subject in its widest scope, telling what has been done, what is doing, and what are the hopes and possibilities for the fixing of Atmospheric Nitrogen for use as fertilizer. Over and over again at the Congress was the diminishing returns from our farming lands bewailed. The Chemical Engineer should be able to say much as to the possibilities of checking this by the use of Nitrogen compounds from the atmosphere. Such a paper should be a "bench mark" as to the state of the art in 1911.

"Soil and its restoratives" might be the subject of another paper to enlighten the dear public on a subject upon which ignorance is not bliss to the farmer. Such a paper bears a close relation to that last mentioned, but there is a field for each.

And in connection with soil restoratives why not hear what our European brethren do in the way of fertilization from sewage? One of the questions frequently mentioned at the Congress was the pollution of our streams with its consequent waste of life, both human and aquatic. What has the Engineer to say as to methods and means whereby this waste may be turned to advantage? This is a subject on which the general public have very little information, and on which the Sanitary Engineer could throw much needed light.

The introduction of practical forestry has called for the services of men of technical training whose function it is to explore and survey large tracts of timber, lay out and construct roads for transportation of logs and for fire lanes, organize and direct the system of patrols and fire protection, and advice clients in all matters pertaining to the preservation of wood in service. Such a man is entitled to be classed as an Engineer, and a paper on these lines would be both interesting, instructive and profitable. The destruction of our forests by fire was frequently referred to in the various addresses at the Congress, but only in general terms. The paper just suggested should tell us specifically how forest fires may be prevented, how the forest should be patrolled, how roads and fire lanes should be laid out, how and where fire stations should be established, and their equipment, the method of fighting a fire once started, and, in fact, go into details of fire protection, with data as to costs per acre, number of men, etc., etc.

While entomology and the study of bugs, beetles, butterflies and moths has never been looked upon as an Engineering study, still it would be interesting to hear from the Entomologist as to how he proposes to head off the gipsy moth, and prevent the waste and devastation that follows in the train of almost any insectiverous pest when once it gets rampant. Whether or not the Entomologist can be classed as an Engineer, he is an important factor in preventing the destruction of plant life, and should be given a hearing at the next Congress. He has a whole lot to say that is interesting and to the point.

What has the Engineer to say on the question of Flood Control? This will be a fine chance for him to tell what he knows upon a very important subject, closely allied to forest preservation. One of the speakers at the Congress, Prof. Graves, touched upon it in the briefest manner.

At the Congress a great deal was said in a very general way upon the development of water power. Upon this whole subject there is far more general ignorance than information. It might be possible to throw some light into the darkness by presenting an outline of the engineering data necessary for consideration of any proposed development. The amount of power available from a stream, or water fall, is almost invariably overestimated and the cost of development underestimated. The public needs enlightenment.

Under the general theme of drainage and reclamation of swamp lands, there is a great deal to be said. A large amount of work has been done and is being done, and a description of the methods, results and costs, illustrated by dredges at work and ditches dug, might be a valuable contribution to the engineering literature on this important field of Conservation.

Much has appeared in popular print and engineering literature relative to irrigation projects, but at the next Congress it would be well if the subject were reviewed and presented up to date.

As might have been expected, the corporations and "special interests" came in for not a little abuse at the Congress; the general impression being that the bigger the operating concern the less regard for economy and the greater waste. It might be well to point out that only operations on a large scale and backed by abundant capital can conserve raw material. Illustrations could be drawn from coal and ore mining and lumbering; and in this connection it would prove enlightening to most people to see, by means of moving pictures, a modern saw-mill in operation, from the log-haul up to the lath and box-board mill. If the pork packers "save everything but the *squeal*"; the saw-mill men save everything but the *"bark,"* and some of that.

These are but a few of the subjects germain to the general subject of Conservation which are primarily of interest to the Engineer. They should be presented before the next Congress if Conservation Congresses are to be more than meetings for mutual admiration and opportunities for oratory.

These suggestions have been made on the supposition that such an Engineering Section would be welcomed as an adjunct to the Conservation Congress. It is doubtful if such would be the case. The object of the Congress seems to be, not a campaign of instruction and education, but an effort to arouse a popular sentiment, with a view to inducing Congressional action that will give to the Executive enlarged powers in dealing with these subjects. But we believe a series of papers such as here suggested would be a valuable addition to Engineering literature, and materially aid the popular movement, whether produced by one Society or by several Societies in co-operation, either as a Section of the Engineering Congress, or independent thereof.

Respectfully submitted,

(Signed) ALEX. M. GOW.

THOS. H. JOHNSON,

Pittsburgh, Penna., Sept. 19, 1910.

SECOND NATIONAL CONVENTION CONGRESS

ST. PAUL, MINN.

September 5, 9, 7, 8 and 9, 1910

PROGRAM

MONDAY, SEPTEMBER FIFTH

MORNING

10 o'clock

Congress called to order by President B. N. Baker, of Baltimore, Maryland

Invocation

The Rt. Rev. John Ireland, Archbishop of St. Paul

Address on Behalf of the State of Minnesota

"The Economic Value of Conservation."

The Hon. Adolph O. Eberhart, Governor of the State of Minnesota

Address on Behalf of the City of St. Paul

The Hon. Herbert P. Keller, Mayor of the City of St. Paul

Address

BY THE PRESIDENT OF THE UNITED STATES

"Our Public Land Laws"

The Hon. Knute Nelson, of Minnesota, Chairman, Committee on Public Lands, United States Senate

AFTERNOON

2 o'clock

Conference of the Governors of the States

Appointment of Presiding Officer

Addresses by the Governors

TUESDAY, SEPTEMBER SIXTH

MORNING

10 o'clock

Invocation

The Rev. Dr. J. S. Montgomery, Pastor of Fowler Methodist Episcopal Church, of Minneapolis

Routine Business

Reports by the State Conservation Commissions

Address, "National Efficiency"

The Hon. Theodore Roosevelt

Appointment of Committees

AFTERNOON

2 o'clock

Appointment of Presiding Officer

"Conservation, The Principle of the Red Cross"

Miss Mabel Boardman, of Washington, D. C. representing the American National Red Cross

"Safeguarding the Property of the People"

The Hon. Francis J. Heney, of California

General Discussion

"The Prevention of Power Monopoly"
The Hon. Herbert Knox Smith, Commissioner of Corporations, United States Department of Commerce and Labor

General Discussion

"The Franchise as a Public Right"
The Hon Herbert S. Hadley, Governor of the State of Missouri

General Discussion

"Water as a Natural Resource"
The Hon. B. A. Fowler, of Phoenix, Arizona, President, National Irrigation Congress

"The Development of Water Power in the Interest of the People"
The Hon. George C. Pardee, of Oakland, California

EVENING

Illustrated Lecture, "Big Game"
Mr. Arthur Radclyffe Dugmore, of New York City

WEDNESDAY, SEPTEMBER SEVENTH

MORNING
9:30 o'clock

Invocation
The Rt. Rev. Samuel Cook Edsall, D. D., of Minneapolis, Bishop of the Protestant Episcopal Church for Minnesota

Routine Business

"The Interest of the Railways of the South in Conservation" ..
Mr. W. W. Finley, of Washington, D. C., President, Southern Railway Company

"The Young Man's Idea"
The Hon. Albert J. Beveridge, United States Senator from Indiana

"Rational Taxation of Resources"
Dr. Frank L. McVey, President, University of North Dakota, Grand Forks, North Dakota

General Discussion
Led by the Hon. John B. White, of Kansas City, Missouri, Chairman, Executive Committee, National Conservation Congress

"Making Our People Count"
Dr. Edwin Boone Craighead, President, Tulane University, New Orleans, Louisiana

"The Press and the People"
Mr. D. Austin Latchaw, of the Kansas City Star, Kansas City, Missouri

"Woman's Influence in National Questions"
Mrs. Emmons Crocker, of Massachusetts, Chairman, Conservation Department, General Federation of Women's Clubs

Reports by the Conservation Committees of National Organizations

AFTERNOON
2 o'clock

Routine Business

Appointment of Presiding Officer

"Soils, Crops, Food and Clothing"
The Hon. James J. Hill, of St. Paul

General Discussion
Led by Mr. Henry Wallace, Editor, Wallace's Farmer, Des Moines, Iowa, and Member, Country Life Commission

"The Farmer and the Nation"
Mr. Walter H. Page, of North Carolina, Editor, World's Work, and Member, Country Life Commission

"Farm Conservation"
Hon. James Wilson, Secretary of the United States Department of Agriculture

"Cattle, Food and Leather"
The Hon. Jonathan P. Dolliver, United States Senator from Iowa

General Discussion
Led by the Hon. Frederick C. Stevens, Representative in Congress from Minnesota

"Conservation and Country Life"
Prof. Liberty Hyde Bailey, Dean, State Agricultural College, Cornell University, New York, and Chairman, Country Life Commission

EVENING

8 o'clock

Illustrated Lecture, "Birds"
Mr. Frank M. Chapman, Curator, Department of Birds, American Museum of Natural History, New York City

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THURSDAY, SEPTEMBER EIGHTH

MORNING

9:30 o'clock

Invocation
The Hon. Rev. Dr. J. A. Krantz, of Duluth, President, Minnesota Conference, Swedish Lutheran Church

Routine Business

"Pan-American Conservation: a Great Opportunity and Responsibility"
The Hon. John Barrett, Director General, Bureau of American Republics, Washington, D. C.

"Conservation as a World-Wide Question"
By a Visiting Representative of a Foreign Nation

"Laws That Should Be Passed"
Mr. Murdo Mackenzie, of Trinidad, Colorado

"This Continent as a Home for Our People"
Dr. W. J. McGee, Expert in Charge of Soil Erosion Investigations, United States Department of Agriculture, and Member, National Conservation Commission

"The Forest and the Nation"
Prof. Henry S. Graves, Forester, United States Department of Agriculture

"Life and Health as National Assets"
Dr. F. F. Wesbrook, of Minneapolis, representing the American Medical Association

AFTERNOON

2 o'clock

Routine Business

Appointment of Presiding Officer

"The Stake the Business Man Has in Conservation"
Mr. Alfred L. Baker, Chairman, Chicago Committee, National Conservation Association

"The Natural Resources Belong to the People"
The Hon. James R. Garfield, Former Secretary of the United States Department of the Interior

General Discussion
Led by the Hon. George C. Pardee of Oakland, California, and the Hon. Newton C. Blanchard; of Shreveport, Louisiana

"Our Resources as the Basis for Business"
Mr. Wallace D. Simmons, of St. Louis, Missouri

"Are We Mining Intelligently?"
Mr. Thomas L. Lewis, of Indianapolis, Ind., President, United Mine Workers of America

"Education and Conservation"
Dr. Elmer Ellsworth Brown, United States Commissioner of Education, United States Department of the Interior

EVENING

8 o'clock

Illustrated Lecture, "Personal and National Thrift"
The Hon. B. N. Baker, of Baltimore, Md., President, National Conservation Congress

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FRIDAY, SEPTEMBER NINTH

MORNING

9:30 o'clock

Invocation
The Rev. Henry C. Swearingen, Pastor, House of Hope Church, St. Paul, Minnesota

Routine Business

"Conservation—True Patriotism"
Mrs. Matthew T. Scott, President General, National Society, Daughters of the American Revolution

"Saving Our Boys and Girls"
The Hon. Ben. B. Lindsey, Judge of the Juvenile Court, Denver, Colorado

"The Conservation Program"
Mr. Gifford Pinchot, President, National Conservation Association

Reports of Committees

No further business coming before the Society, the papers of the evening were read: "Contractor's Plants, Types, Layouts and Methods of Operation," by Frederick E. Field, and "Forms for Concrete," by J. D. Stevenson.

The ensuing discussion was participated in by Messrs. Mor-

ris Knowles, D. H. Littell, Emil Swensson, L. P. Blum, M. Hokanson, B. A. Ludgate, F. E. Field and J. D. Stevenson.

The meeting adjourned at 10:15 P. M.

ELMER K. HILES,
Secretary.

STRUCTURAL SECTION

Th regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 6 September, 1910, at 8:20 P. M.; Chairman V. R. Covell presiding, 60 members and visitors being present.

The minutes of the last meeting, held 10 May, were read and approved.

No further business coming before the Section, the paper of the evening on "Recent Practice in Retaining Wall Construction by the City of Pittsburgh," was read, by Mr. C. M. Reppert.

The ensuing discussion was participated in by Messrs. C. F. W. Rys, Willis Whited, A. R. Archer, L. P. Blum, R. B. Woodworth, E. Godfrey, J. D. Stevenson and C. M. Reppert.

The meeting adjourned at 10:45 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Oliver Building, Pittsburgh, Friday, 15 July, 1910, at 4:45 P. M., President E. K. Morse presiding, Messrs. Riddle, Raymer and the Secretary being present.

The minutes of the last regular meeting, held 13 June, were read and approved.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board on 13 June, 1910, were duly elected to membership:

ACTIVE.

Craig, G. B.,
Frohrieb, L. C.,
Hice, Richard R.,
Irvin, C. R.,
Kimball, Ralph E.,
Manning, Harry G.,
Power, Walter J.,
Skinkle, Wm. B.,
Price, C. S.,
Straub, T. A.
Warner, Arthur A.,
Wood, Geo. R.,
Gerber, L. C.

JUNIOR.

Abbe, Walter, Jr.,
Anderson, Martin J.,
Bell, Glibert A.,
Cochran, J. S.,
Kline, Robert S.,
Obermeyer, W. S.

Applications were received from the following gentlemen and their names ordered published to the Society.

ACTIVE.

Davenport, Arthur E.,
Wagner, Arthur A.,
Dickerson, J. H.,
Dawson, Thos. W.,
Hirsh, Wm. L.
Hammel, Victor F.,
Kingsbury, Albert,
Keller, Wm. L.,
Myers, A. C.,
McDowell, J. S.,
Scheidenhelm, F. W.,
Oberly, A. D.,
Stratton, W. C.

ASSOCIATE.

Cooper, A. P.

JUNIOR.

Fahnestock, James M.,
Henderson, J. H.,
Springer, Thurman F.,
Sturgiss, Joseph E.

The report of the Secretary, showing the financial condition of the Society at close of business 30 June, 1910, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The meeting adjourned at 5:40 P. M.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Friday, 23

September, 1910, at 4:50 P. M., President Morse, Messrs Craver, Lyons, Raymer, Whited, Covell and the Secretary being present.

The minutes of the last regular meeting, held 15 July were read and approved.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board on 15 July, 1910, were duly elected to membership:

ACTIVE.

Dickerson, J. H.,	Dawson, Thos. W.,
Hammel, Victor F.,	Hirsh, W. L.,
Keller, W. L.,	Kingsbury, Albert,
McDowell, J. S.,	Myers, A. C.,
Oberly, A. D.,	Scheidenheim, F. W.,
Stratton, W. C.,	Wagner, Arthur A.

ASSOCIATE.

Cooper, A. P.

JUNIOR.

Fahnestock, James M.,	Henderson, J. H.,
Springer, Thurman F.,	Sturgiss, Joseph E.

The application for membership of A. E. Davenport was cancelled at his request.

Requests for reinstatement were received from the following gentlemen whose names were ordered replaced on the roll of membership:

C. A. Finley, who joined the Society in April, 1903; and C. L. Hastings, who joined the Society in March, 1902.

Applications were received from the following gentlemen, and their names ordered published to the Society:

ACTIVE.

Allen, Irving Cowan,	Flagg, Samuel Blarry,
Grundy, J. W. H.,	Hofwing, Fritz,
Howell, Spencer P.,	McArthur, C. D.,
Rose, Floyd,	Stone, Lauson,

Utley, J. C.

JUNIOR.

Elliott, J. E., Westbrook, G. H., Witherow, W. P.

The report of the Secretary, showing the financial condition of the Society at close of business July 31st and August 31st, having been previously audited by the Finance Committee, were approved and bills ordered paid.

The Secretary announced as a result of ballot for revision of By-Laws, the receipt of 160 ballots, all in the affirmative.

Mr. Craver, Chairman of Publication Committee, presented the report of Thomas H. Johnson and Alex M. Gow, delegates representing the Society at the National Conservation Congress, held at St. Paul, September 5 to 9th inclusive.

The meeting adjourned at 5:25 P. M.

ELMER K. HILES,
Secretary.

REGULAR MONTHLY MEETING.

The 305th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society rooms, Oliver Building, Pittsburgh, Tuesday, 18 October, 1910, at 8:20 P. M., President Morse presiding, 47 members and visitors being present.

The minutes of the regular meeting held 20 September, were read and approved.

The Board of Direction reported the election of 12 Active members, one Associate and four Juniors; the receipt of nine applications for Active membership, and three for Junior at the meeting of 23 September; also the election of nine Active members, three Juniors, and the receipt of six applications for Active membership and three for Junior at the meeting of 14 October 1910.

No further business coming before the Society, the paper of the evening on "Material Economics," was read by T. D. Lynch.

The ensuing discussion was participated in by Messrs. J. H. Baker, T. J. Wilkerson, R. B. Woodworth, J. J. Shuman, C. B. Albree, H. W. Fisher, R. A. Cummings, S. E. Duff, A. Stucki, Lee C. Moore, Willis Whited, Edward Godfrey and T. D. Lynch.

Meeting adjourned at 9:50 P. M.

ELMER K. HILES,
Secretary.

MECHANICAL SECTION.

The regular bi-monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 4 October, 1910, at 8:10 P. M.; Chairman Stucki presiding, 90 members and visitors being present.

The minutes of the last meeting, held 7 June, were read and approved.

No further business coming before the Section, the paper of the evening on "A Modern Central Heat, Light and Power Station," was read by Mr. W. G. Boyle.

The ensuing discussion was participated in by Messrs. H. D. James, E. D. Dreyfus, Cadwallader Evans, Jr., G. H. Danforth, S. E. Duff, and W. G. Boyle.

The meeting adjourned at 10:05 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Friday, 14 October, 1910, at 4:45 P. M., President Morse, presiding, Messrs Taylor, Craver, Lyons, Whited, Handy, Covell and the Secretary being present.

The minutes of the last regular meeting, held 23 September, 1910, were read and approved.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board on 23 September, were duly elected to membership:

ACTIVE

Allen, Irving Cowan
Flagg, Samuel Barry
Grundy, J. W. H.
Hofwing, Fritz
Howell, Spencer P.
McArthur, C. D.
Rose, Floyd
Stone, Lauson
Utley, J. C.

JUNIOR

Elliott, J. L.
Witherow, W. P.
Westbrook, G. H.

Applications were received from the following gentlemen, and their names ordered published to the Society:

ACTIVE

Black, Frank J.
Danks, Alfred Clement
Keebler, H. J.
Jackson, John
Burke, Albert G.
Day, Rodney D.
Waddell, Fred W.

ASSOCIATE

Griffin, E. J.

JUNIOR

Buente, Willard H.
Porterfield, Robt. A.
Routh, Charles M.

The Secretary announced the death of J. H. Wood, who joined the Society in June, 1906.

The report of the Secretary, showing the financial condition of the Society at close of business, 30 September, 1910, having been previously audited by the Finance Committee, was approved, and bills ordered paid.

The meeting adjourned at 5:30 P. M.

ELMER K. HILES,
Secretary.

EMPLOYMENT BULLETIN

The Society has found it can do an important work as the medium for securing better position for its members who desire them. The Secretary gives this his personal attention, and is desirous of receiving prompt notification both of positions open and of men available. Notices are not repeated except upon special request.

POSITIONS OPEN

023 Wanted: Capable man to take charge of drawing room; experienced in structural concrete design. Correspondence solicited from high grade men only.

034 Wanted: Young men with electrical and mechanical educations for specification and field engineering work. State age, salary expected and extent of education and experience. Work is in Western Pennsylvania. Expenses will be paid when out of town. Good chances for advancement if ability is shown.

035 Wanted: A young man who has had schooling in mechanical engineering, preferably a graduate. Should have had some experience.

036 Wanted: A young man with experience in surveying and making field notes. Technical graduate preferred.

037 Wanted: Several young men with electrical schooling. Experience not required, but preferred.

038 Wanted: Civil Engineer with experience on sewer work. Job will last three months.

MEN AVAILABLE

40 Structural Engineer desires position as assistant to Chief Draftsman, squad boss or checker. Experienced on bridge and structural work.

52 Mining Engineer desires position. Have filled positions as Assistant General Superintendent and Chief Engineer with company operating a number of coal mines. Large experience on construction work.

67 A graduate of the Massachusetts Institute of Technology, with 14 years experience on large water works construction, desires engagement on engineering work or with contractor.

69 Recent graduate from Lehigh University in mechanical engineering course desires position.

70 Engineer with 12 years experience in electrical manufacturing and designing desires position. Experienced in factory management. Technical education.

71 Civil Engineer experienced on railroad location and construction work, etc., desires position.

72 Young engineer desires position as level man.

73 Young engineer with several years experience in general work on surveys, sewer construction, railroad and bridge work desires position. Technical education.

75 Mechanical Draftsman, experienced in general and special work desires position—36 years old.

REGULAR MONTHLY MEETING

The 306th regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held at the Society rooms, Oliver Building, Pittsburgh, Tuesday, 15 November, 1910, at 8:15 P. M., President Morse presiding, 151 members and visitors being present.

The minutes of the last regular meeting, held 18 October, were read and approved.

The Board of Direction reported the election of seven Active members, one Associate, and three Juniors; the receipt of eleven applications for Active membership, two Juniors and two Junior Students, at the meeting of 7 November, 1910.

No further business coming before the Society the paper of the evening on "The Electric Furnace: Its Place in Siderurgy," was read by Mr. P. McN. Bennie, of Niagara Falls, N. Y.

The ensuing discussion was participated in by Messrs. H. W. Fisher, N. W. Storer, J. O. Handy, C. F. Scott, F. N. Speller, Brent Wiley, John Todd, Arnold Stucki, P. P. Reese, M. A. Smith and P. McN. Bennie.

The meeting adjourned at 10:10 P. M.

ELMER K. HILES,
Secretary

STRUCTURAL SECTION

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, 1 November, 1910, at 8:00 P. M., Chairman V. R. Covell presiding, 59 members and visitors being present.

The minutes of the last meeting, held 6 September, were read and approved.

No further business coming before the Section, the paper of the evening on "The Preservation of Structural Timbers from Decay," by Mr. C. P. Winslow, Engineer, U. S. Forest Service, was read by the Secretary in the absence of the author.

The ensuing discussion was participated in by Messrs. G. S.

Davison, A. R. Raymer, V. R. Covell, L. P. Blum, Willis Whited, G. B. Shipley, N. S. Sprague, and Albert Kingsbury.

The meeting adjourned at 10:35 P. M

ELMER K. HILES, Secretary

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Monday, November 7, 1910, at 4:45 P. M.; President Morse presiding, Messrs. Lyons, Handy, Raymer, Grace, Whited, Riddle and the Secretary being present.

The minutes of the last regular meeting held 14 October, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society in the announcement covering the 1 November meeting, pursuant to the action of the Board on the 14 October, were duly elected to membership:

ACTIVE

Black, Frank J. — Burke, Albert G.
Danks, Alfred C. — Day, Rodney D.
Jackson, John H. — Keebler, Homer J.
Waddell, Fred W.

ASSOCIATE

Griffin, Edward J.

JUNIOR

Buente, Willard H. — Porterfield, R. A.
Routh, Charles M.

Applications were received from the following gentlemen, and their names ordered published to the Society:

ACTIVE

Baker, Louis F. — Deckman, Edward J.
Gressly, Oscar E. — Kuhns, Frank S.
Lesh, J. H. — McDowell, Elmer K.
Porter, Ralph W. — Samans, Walter
Schmidt, R. L. — Smitmans, John A.
Thornton, Chas.

JUNIOR

Appel, Harry G. Kaul, Edwin O.

Matchneer, William W.

JUNIOR (STUDENT GRADE)

Saulters, George C.

A request for reinstatement was received from F. V. McMullin, who joined the Society in September 1902, and resigned in January 1908. His name was ordered replaced on the Society records.

The report of the Secretary, showing the financial condition of the Society at close of business 31 October, 1910, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The following report of the Nominating Committee was presented to the President and Board of Direction of the Engineers' Society of Western Penna.:

"Dear Sirs:

Your Nominating Committee beg to submit the following nominations as the unanimous choice of the Committee as candidates for the several offices to be filled:

President, Walther Riddle.

Vice President, S. P. Grace, (2 years).

Treasurer, A. E. Frost.

Directors, Arnold Stucki, Samuel E. Duff.

It was voted that the Nominating Committee recommend the gentlemen named and request that they be notified and asked if they can serve.

Nominating Committee:

E. B. Taylor, Chairman,
James K. Lyons,
Morris Knowles,

7 November, 1910. Chester B. Albree, Secretary.

The report of the Nominating Committee was approved and ordered published to the Society in the November Announcement.

The meeting adjourned at 5:40 P. M.

ELMER K. HILES, Secretary.

REGULAR MONTHLY MEETING.

The 307th regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the Lecture Hall of the Carnegie Institute, Tuesday evening, 20 December, at 8:15 P. M.; President Morse presiding, 450 members and visitors being present.

The minutes of the last regular meeting held 15 November, 1910, were read and approved.

No further business coming before the Society, the paper of the evening, on "The Construction Details of the Panama Canal," was read by Lieut. Col. William L. Sibert.

A large number of exceptionally fine slides were used by Col. Sibert during the evening, which showed clearly many of the more important details of construction in connection with the locks and dam at Gatun.

The meeting adjourned at 9:30 P. M.

ELMER K. HILES,
Secretary.

MECHANICAL SECTION.

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Oliver Building, Pittsburgh, Tuesday, December 6, 1910, at 8:15 P. M., 89 members and visitors being present.

The minutes of the last meeting held 4 October, were read and approved.

No further business coming before the Section, the paper of the evening was presented by Mr. E. J. Fithian, Manager of the Bessemer Gas Engine Company.

The ensuing discussion was participated in by Messrs. Flint, Schatz, Diescher, Miriam, Ellis, Leland, McKee, Macartney, and Griffin.

The meeting adjourned at 10:15 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Oliver Building, Pittsburgh, Friday, 9 December, 1910, at 4:45 P. M.; President Morse presiding, Messrs. Handy, Riddle, Raymer, Craver, Grace, Whited, Chester, Covell and the Secretary being present.

The minutes of the last regular meeting held 7 November, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society, pursuant to the action of the Board on 7 November, were duly elected to membership:

ACTIVE.

Baker, Louis F.,
Deckman, Edward J.,
Gressly, Oscar E.,
Kuhns, Frank S.,
Lesh, J. H.,
McDowell, Elmer K.,
Porter, Ralph W.,
Samans, Walter,
Schmidt, R. L.,
Smitmans, J. A.,

Thornton, Charles.

JUNIOR.

Appel, Harry G.,
Matchneer, W. W.

JUNIOR (STUDENT)

Kaul, Edwin O.,
Saulters, George C.

A request for reinstatement was received from Frederick Crabtree, who joined the Society in March 1892, and resigned in February, 1898. His request was granted and his name ordered placed on the Society rolls, his membership becoming effective January 1, 1911.

Applications were received from the following gentlemen, and their names ordered published to the Society:

ACTIVE.

Ayers, H. B.,
Baker, Charles I.,
Eisenhart, H. W.,
James, Joseph H.,
McCullough, Francis M.,
Metcalf, H. E.,
Norris, Geo. L.,
Williams, W. C.

JUNIOR.

Barnes, Hugh, Reed, James K.

JUNIOR (STUDENT)

Witte, Herman C.

The report of the Secretary, showing the financial condition of the Society at close of business 30 November, 1910, having been previously audited by the Finance Committee, was approved and bills ordered paid.

Meeting adjourned at 5:45 P. M.

ELMER K. HILES,
Secretary.

A special meeting of the Board of Direction was held in the Society rooms 28 December, 1910, at 4:45 P. M.; President Morse, presiding, Messrs. Craver, Grace, Chester, Riddle, Handy, Raymer, Frost and the Secretary being present.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board 9 December, 1910, they were duly elected to membership, effective 1 January, 1911:

ACTIVE.

Ayers, H. B., Norris, G. L.,
Cooper, W. M., Baker, Chas. I.,
Eisenhart, H. W., James, J. H.,
McCullough, F. M., Metcalf, H. E.,
Williams, W. C.

JUNIOR.

Barnes, Hugh, Reed, James K.

JUNIOR (STUDENT)

Witte, Herman C.

The meeting adjourned.

ELMER K. HILES,
Secretary.

PROCEEDINGS

—OF THE—

ENGINEERS' SOCIETY

OF WESTERN PENNSYLVANIA

INCORPORATED 1880

Edited by the Secretary under the direction of the Publication Committee.
Published Monthly, except August and September.

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All papers, on their acceptance by the Publication Committee, become the property of the Society, and it lies within the discretion of the Committee to publish them in whole or in part. This will always be done, if possible, with the approval of the author.

The Society, however, does not hold itself responsible for opinions expressed by its members.

The Society will mail monthly, except August and September, to its members, correspondents and advertisers, postage prepaid, a copy of the Proceedings; each one containing the minutes of, and the papers read at the regular meeting and meetings of the Mechanical and Structural Sections.

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EMPLOYMENT BULLETIN

The Society has found it can do an important work as the medium for securing better positions for its members who desire them. The Secretary gives this his personal attention, and is desirous of receiving prompt notification both of positions open and of men available. Notices are not repeated except upon special request.

MEN AVAILABLE

40 Structural Engineer desires position as assistant to Chief Draftsman, squad boss or checker. Experienced on bridge and structural work.

52 Mining Engineer desires position. Have filled positions as Assistant General Superintendent and Chief Engineer with company operating a number of coal mines. Large experience on construction work.

67 A graduate of the Massachusetts Institute of Technology, with 14 years experience on large water works construction, desires engagement on engineering work or with contractor.

69 Recent graduate from Lehigh University in mechanical engineering course desires position.

70 Engineer with 12 years experience in electrical manufacturing and designing desires position. Experienced in factory management. Technical education.

71 Civil Engineer experienced on railroad location and construction work, etc., desires position.

73 Young engineer with several years experience in general work on surveys, sewer construction, railroad and bridge work desires position. Technical education.

75 Mechanical Draftsman, experienced in general and special work desires position—36 years old.

76 Recent graduate from Lehigh University, Mech. Engrg., desires position.

77 Mechanical draftsman desires position. Experienced in general drafting and checking.

78 Recent technical graduate in civil engineering desires position. Experienced on municipal work and sewage disposal plant.

79 Wanted: Position as Structural or Contracting Engineer by a

graduate engineer with 14 years varied experience in drafting room, shop and office on all classes of structural and plate work. At present holds responsible position with a steel construction company.

80 Position wanted by young civil engineer with seven years experience on construction work. Has had charge of field party and worked for a number of years on filter construction. Desire especially position with a water company.

81 Structural Engineer, seven years experience desires position. Experience covers designing and checking structural steel and reinforced concrete work.

82 Rolling Mill and Steel Works Engineer of long experience desires to make change. Capable of laying out entire plant and designing machinery for same. Would consider taking stock in a manufacturing company.

83 Mechanical Engineer with six years experience in railroad work and power plant design and construction, desires position.

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American Machinist.
American Society of Civil Engineers, Proceedings.
American Society of Mechanical Engineers, Proceedings.
American Water Works Association, Bulletin.
American Railway Engineering and Maintenance of Way Association, Bulletin.
Analyst, The.
Appleton's Magazine.
Annales de L'Association des Ingenieurs de Grand.
Annaes Scientificos de Academia Polytechnia Porto.
Anales de la Sociedad Cientifica Argentina.

Bi-Monthly Bulletin of Amer. Institute of Mining Eng.
Building Management.

Canadian Electrical News.
Cassier's Magazine.
Chamber of Mines, Monthly Journal of the
Chemical News.
Coal.
Coal Trade Bulletin.
Compressed Air.
Concrete.
Contractor, The.
Cornell Civil Engineer.

Electric Journal.
Electric Railway Journal.
Electrical Review.
Electrical World.
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Engineering Magazine.
Engineering & Mining Journal.
Engineering News.
Engineering Record.
Engineering Review.
Engineering—Contracting.
Engineers' Club of Philadelphia, Proceedings.
Engineering Journal, Canada.
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Harvard Engineering Journal.
Heating & Ventilating Magazine.

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Industrial Engineering.
Industrial Magazine.
Industrial World.
Insurance Engineering.
Iron Age.
Iron Trade Review.

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Journal of the Association of Engineering Societies.
Journal of the Franklin Institute.
Journal of the Society of Arts.
Journal of the Society of Chemical Industry.
Journal of the U. S. Artillery.
Journal of the Western Society of Engineers.

Les Mois Scientifique et Industriel.
Leslie's Weekly.
Locomotive.

Machinery.
Maschinen Konstrukteur.
Mechanical World.
Metallurgical & Chemical Engineering.
Mexican Mining Journal, The
Mines & Minerals.

Monthly Journal of the Chamber of Mines.
Municipal Engineering.
McClure's Magazine.

National Engineer.

Official Gazette, U. S. Patent Office (Wash.)
Official Journal, Patents, (London).
Ores and Metals.
Outlook.

Physical Review.
Power.
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Proceedings of the Engineering Association of the South.
Proceedings of the Amer. Institute of Electrical Engineers.
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Progressive Age.

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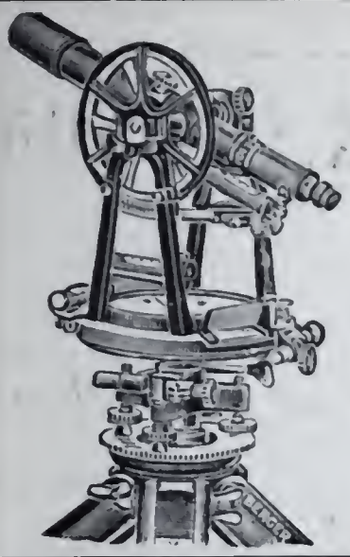

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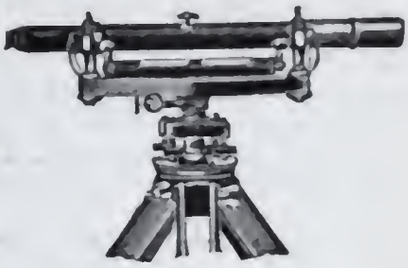

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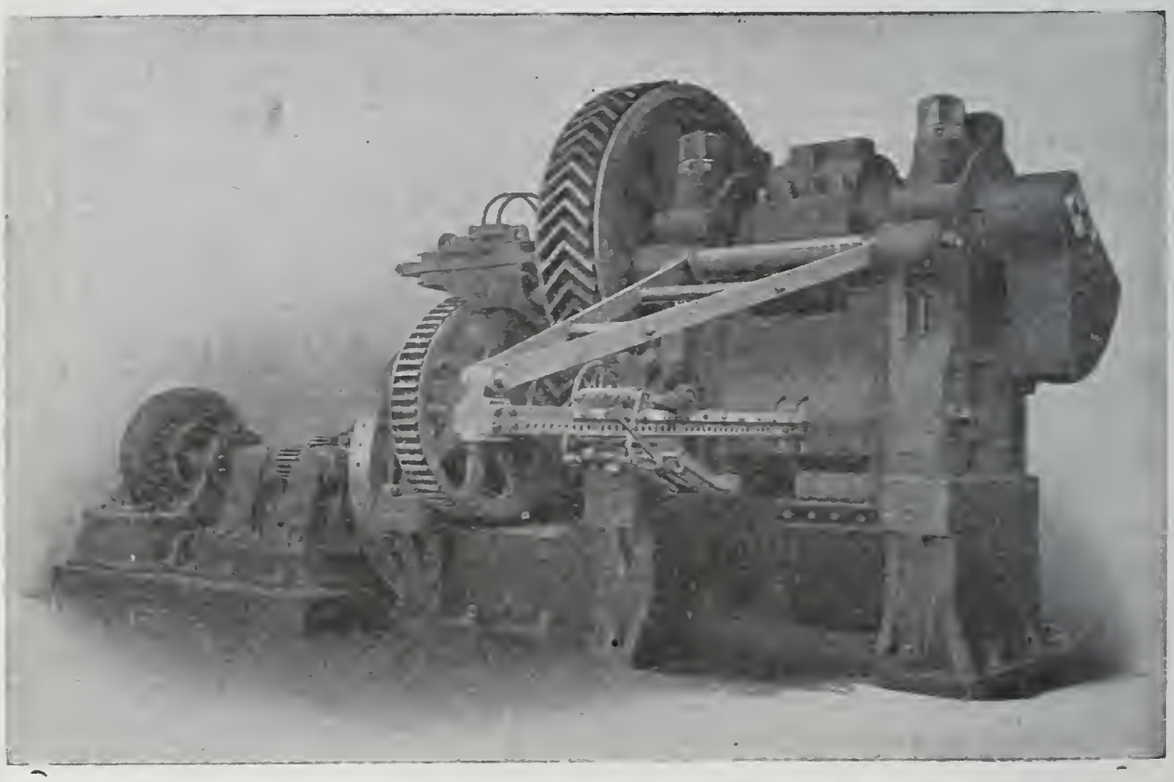

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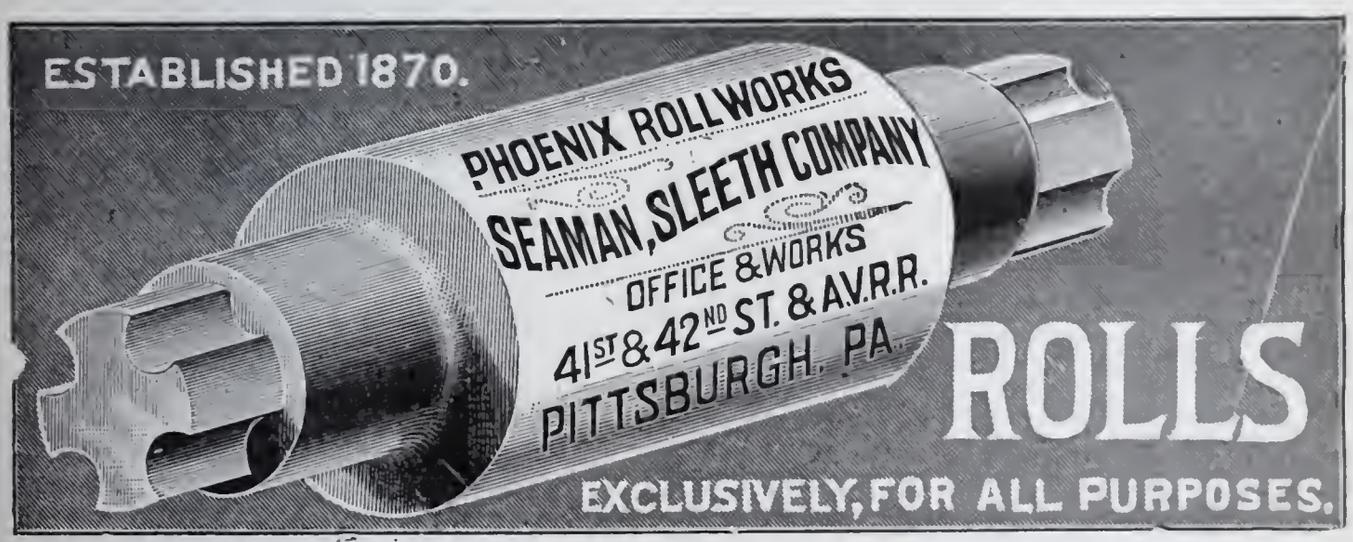

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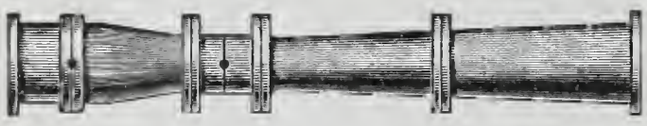

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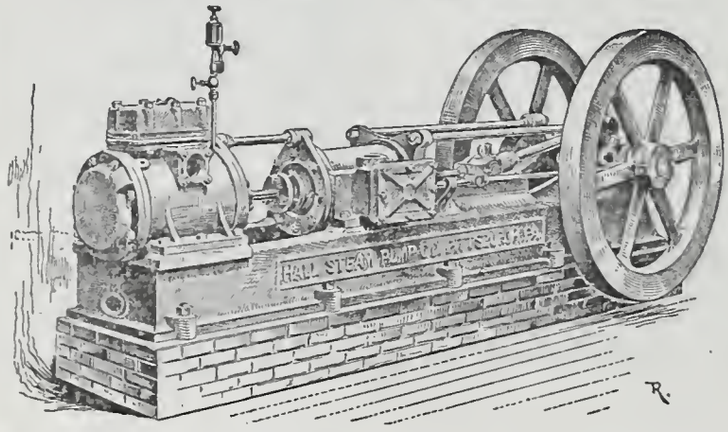

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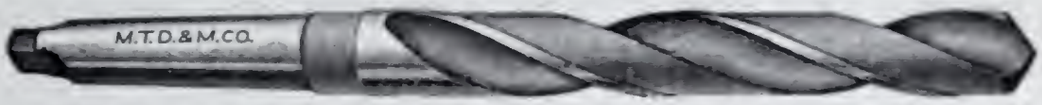

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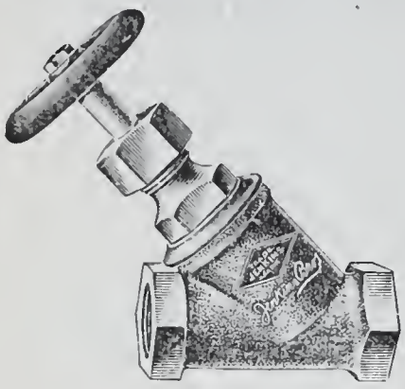

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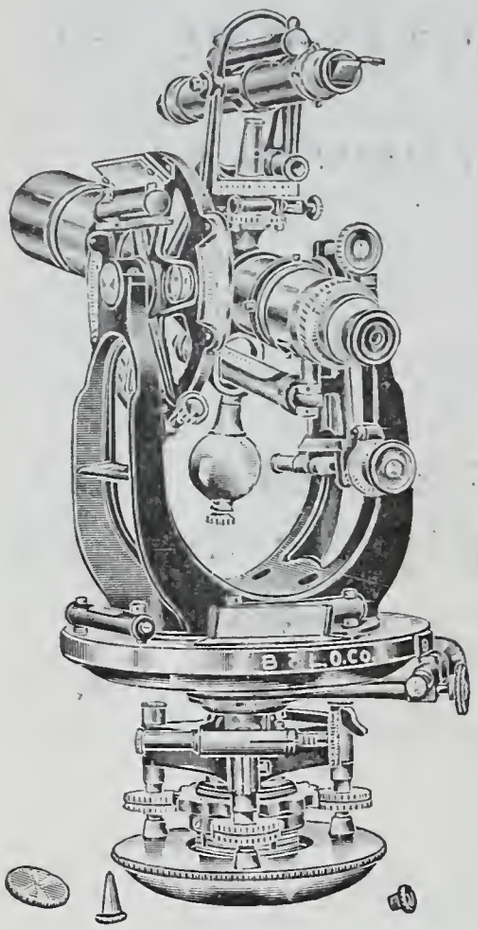

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